GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 1/26/81

Project Title: Continuous Operation of the French Meteor Radar on Puerto Rico 1980-1982

Project No: G-35-686

Project Director: Dr. R. G. Roper

Sponsor: *National Science Foundation*

Agreement Period: From 8/1/80 Until ~~1/31/82~~ 7/31/83 *(Grant Period)*

(Includes 6 month unfunded flexibility period)

Type Agreement: *Grant No.* ATM-8012705 *, dated* 1/12/81

Amount:

| | | |
|---|---|---|
| $ 54,000 | *NSF* | G-35-686 |
| 2,695 | *GIT* | G 35-356 |
| $ 56,695 | *TOTAL* | |

Reports Required: *Annual Progress Report ; Final Project Report*

Sponsor Contact Person (s):

Technical Matters

*NSF Program Official*

Mr. Vincent B. Wickwar

*National Science Foundation*
*Washington, D. C. 20550*
202/~~xxxx~~ 632 357-7619

Contractual Matters
(thru OCA)

*NSF Grants Official*

Mr. Lee A. DeHerrera

*Division of Grants and Contracts*
*Directorate for Administration*
*National Science Foundation*
*Washington, D. C. 20550*
202/~~632~~ 357-9602



Defense Priority Rating: *N/A*

Assigned to: Geophysical Sciences (School/Laboratory)

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GEORGIA INSTITUTE OF TECHNOLOGY　　　　OFFICE OF CONTRACT ADMINISTRATION

## SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date January 27, 1984

Project No. G-35-686　　　　School/~~XXXX~~ Geo. Sci.

Includes Subproject No.(s) NONE

Project Director(s) Dr. R.G. Roper　　　　GTRI / ~~XXXX~~

Sponsor National Science Foundation

Title "Continuous Operation of the French Meteor Radar on Puerto Rico"

Effective Completion Date: 7/31/83 (Performance) 10/31/83 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [X] ~~XXXXXXXXXXXX~~ Final ~~XXXXXXXXX~~ FCTR
- [ ] Closing Documents
- [X] Final Report of Inventions (if positive)
- [X] Govt. Property Inventory & Related Certificate
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GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF GEOPHYSICAL SCIENCES
Atlanta, Georgia 30332
(404) 894 2857

September 25, 1981

Dr. Vincent Wickwar
Atmsopheric Research (Aeronomy)
National Science Foundation
Room 644
1800 G Street, NW
Washington, D.C. 20550

Subject: Annual Technical Letter, NSF Grant No. ATM80-12705 (Georgia Tech Project G-35-686) "Continuous Operation of the French Meteor Wind Radar at Ramey, Puerto Rico, 1980-1982."

Dear Vince:

While we did not reach the goal of routine continuous operations throughout the whole of the grant period, this has been our best year so far. Our biggest problem in 1980 was contamination of the data by F region backscatter. This, combined with power outages and "brownouts," (the latter resulting in two quite expensive computer failures) limited the useful periods of data gathering to August 11-23 and October 6-15. The August period coincided with measurements of D region drifts by Dr. Takehiko Aso, of the University of Kyoto, using the Arecibo Observatory 430 MHz radar, and these results are being prepared for publication.

A transmitter power outage necessitated by rerouting of power lines for the construction fo the USDA Quarantine Station at Ramey, and a tight budgetary situation delayed operation until late February. During this interval, the Puerto Rican Power Company also installed new power lines to the receiver site at no cost to the project. (The new line was requested by the U.S. Air Force Solar Observatory, where the receiving trailer is located. Our relationship with the Solar Observatory has been one of mutual cooperation, which has definitely benefitted the project.)

Data was gathered routinely from February 24 through May 1, which is by far the longest interval of equatorial mesopause dynamics data ever collected.

A considerable amount of time has been spent in identifying F region backscatter signatures, and attempting to maximize the meteor wind data retrieval during the daytime and evening hours that the backscatter is present. The backscatter is a solar controlled phenomena, and is decreasing as solar activity declines (previous experience at midlatitudes has found the problem to exist only for the two years about sunspot maximum).

As indicated in my letter of April 27, operation during the coming year will consist of five campaigns of approximately 10 days each in October and December 1980, and February, April and June in 1981. The October and December 1980 campaigns will most likely be combined into a three week campaign in November, coinciding with the proposed Jicamarca observations to be performed by Dr. Aso, and the VHF scatter experiments by Dr. Jurgen Rottger (Max Planck Institute, Lindau) using the Arecibo dish. The rest of the observations have been chosen to best fall within the 1981-1982 MAP calendar, with particular emphasis being focused on incoherent scatter coordinated observation days.

The data gathered by this project will enable us, for the first time, to answer some of the questions regarding the synoptic meteorology of the equatorial mesopause. Coupled with the simultaneous observations by the Georgia Tech Radio Meteor Wind Facility, evidence for the occasional penetration to midlatitudes of the equatorial circulation which I have previously hypothesized, should be forthcoming.

Once again, my thanks to you and NSF for your support.

Yours sincerely,

Dr. R. G. Roper
Principal Investigator

RGR/ej

G-35-686

FINAL TECHNICAL REPORT
GT/PROJECT NO. G-35-686

# CONTINUOUS OPERATION OF THE FRENCH METEOR WIND RADAR AT RAMEY, PUERTO RICO, 1980–82

By

R. G. Roper

Research Supported by

THE ATMOSPHERIC RESEARCH SECTION (AERONOMY)
NATIONAL SCIENCE FOUNDATION

Under

Grant No. ATM-8012705

Contract Period August 1, 1980 – July 31, 1983

December 1983

**GEORGIA INSTITUTE OF TECHNOLOGY**
**A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA**
**SCHOOL OF GEOPHYSICAL SCIENCES**
**ATLANTA, GEORGIA 30332**

1983

# APPENDIX VI

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

## FINAL PROJECT REPORT
NSF FORM 98A

*PLEASE READ INSTRUCTIONS ON REVERSE BEFORE COMPLETING*

**PART I—PROJECT IDENTIFICATION INFORMATION**

| 1. Institution and Address | 2. NSF Program | 3. NSF Award Number |
|---|---|---|
| School of Geophysical Sciences<br>Georgia Institute of Technology<br>Atlanta, Georgia 30332 | ATMOSPHERIC SCIENCES | ATM 80-12705 |
| | 4. Award Period<br>From 8/1/80 To 7/31/83 | 5. Cumulative Award Amount<br>$110,000 |

6. Project Title

Continuous Operation of the French Meteor Radar on Puerto Rico, 1980-82

**PART II—SUMMARY OF COMPLETED PROJECT** *(FOR PUBLIC USE)*

The objective of continuous operation of the system was achieved for the interval February 24, 1981 through June 29, 1981; the wind results measured over the height range from 80 to 100 km for this interval have been reduced and were represented at the Ground Based Studies of the Middle Atmosphere Symposium held in Schwerin, GDR, May 9-13, 1983. The proceedings of this symposium are to be published as a Middle Atmosphere Program (MAP) Handbook.

The major findings of this study can be summarized as follows: prevailing wind circulation in the equatorial zone is characterized by stronger winds, and more pronounced easterly circulation than observed at middle and higher latitudes; the diurnal tide is a dominant feature of the circulation, particularly at the equinox, when its amplitude may exceed 80 meters/sec; the semidiurnal tide is also stronger than at midlatitudes.

Three factors contributed to the less than satisfactory results and the discontinuance of this project - slow deterioration of the system in the tropical environment; frequent power outages and brownouts; and the F region backscatter around solar cycle maximum.

The equipment has been donated by the French government to the University of Puerto Rico. There are no plans for its further use as a meteor radar.

**PART III—TECHNICAL INFORMATION** *(FOR PROGRAM MANAGEMENT USES)*

| 1. ITEM *(Check appropriate blocks)* | NONE | ATTACHED | PREVIOUSLY FURNISHED | TO BE FURNISHED SEPARATELY TO PROGRAM: Check (√) | TO BE FURNISHED SEPARATELY TO PROGRAM: Approx. Date |
|---|---|---|---|---|---|
| a. Abstracts of Theses | X | | | | |
| b. Publication Citations | X | | | | |
| c. Data on Scientific Collaborators | | X | | | |
| d. Information on Inventions | X | | | | |
| e. Technical Description of Project and Results | | | | X | 12/31/83 |
| f. Other *(specify)* | | | | | |

| 2. Principal Investigator/Project Director Name *(Typed)* | 3. Principal Investigator/Project Director Signature | 4. Date |
|---|---|---|
| Dr. R. G. Roper | | 11/21/83 |

NSF Form 98A (5-78) Supersedes All Previous Editions

Form Approved OMB No. 99R0013

# CONTINUOUS OPERATION OF THE FRENCH METEOR WIND RADAR AT RAMEY, PUERTO RICO, 1980-82


R. G. ROPER

Georgia Institute of Technology
School of Geophysical Sciences
Atlanta, Georgia 30332



Final Technical Report on Research Supported by the Atmospheric Research Section (Aeronomy) of the National Science Foundation, under Grant No. ATM80-12705

Georgia Tech Project No. G-35-686

Contract Period AUGUST 1, 1980 - JULY 31, 1983

DECEMBER, 1983

ATTACHMENT TO FORM 98A, NSF PROJECT ATM 80-12705

1. Willard J. Cyphers, Research Associate

   Responsible for operation and maintenance of the system at Ramey

2. James Fulford - Graduate Student

3. P. R. Jayakumar - Graduate Student

4. Dr. M. I. Ahmed

   UNESCO Post Doctoral Scholar from Andhra University, India

(2, 3, and 4 were not funded by the grant, but assisted in data reduction, analysis and interpretation).

CONTENTS

# SUMMARY

The objective of continuous operation of the system was achieved for the interval February 24, 1981 through June 29, 1981; the wind results measured over the height range from 80 to 100 km for this interval have been reduced and were represented at the Ground Based Studies of the Middle Atmosphere Symposium held in Schwerin, GDR, May 9-13, 1983. The proceedings of this symposium are to be published as a Middle Atmosphere Program (MAP) Handbook.

The major findings of this study can be summarized as follows: prevailing wind circulation in the equatorial zone is characterized by stronger winds, and more pronounced easterly circulation than observed at middle and higher latitudes; the diurnal tide is a dominant feature of the circulation, particularly at the equinox, when its amplitude may exceed 80 meters/sec; the semidiurnal tide is also stronger than at midlatitudes.

Three factors contributed to the less than satisfactory results and the discontinuance of this project - slow deterioration of the system in the tropical environment; frequent power outages and brownouts; and the F region backscatter around solar cycle maximum.

The equipment has been donated by the French government to the University of Puerto Rico. There are no plans for its further use as a meteor radar.

# Chapter I.

## Introduction.

This report details work carried out as a continuation of NSF Grant ATM-7810089, "Continuous Operation of the French Meteor Wind Radar at Ramey, Puerto Rico, 1978-80". The Final Report on that grant (Roper, 1981), contained a description of the hardware and software of the French radar, which was provided by the Centre Nationale d'Etudes de Telecommunications (CNET), and the prevailing wind, 24 and 12 hour tides for the intervals during 1980 of May 15 - June 11, August 11 - August 23, and October 6 - October 15.

The winds reported in the present work were measured between February 24 and May 14, and June 24-29, 1981. This is the longest sequence of meteor winds yet measured in the equatorial zone (Ramey is 18°N, 64°W).

The rest of this chapter is devoted to "Meteor Wind Results from Atlanta, U.S.A., and Ramey, Puerto Rico", presented at the Symposium on Ground Based Studies in the Middle Atmosphere, Schwerin, German Democratic Republic, May 9-13, 1983. Papers presented at this symposoum are scheduled to appear in a future Handbook for MAP.

# Meteor Wind Results from Atlanta, U.S.A. and Ramey, Puerto Rico

by

R. G. Roper
School of Geophysical Sciences
Georgia Institute of Technology
Atlanta, Georgia 30332

## A B S T R A C T

Results obtained using the French (CNET) Meteor Wind Radar at Ramey, Puerto Rico (18°N, 67°W), and the Georgia Tech Radio Meteor Wind Facility in Atlanta, U.S.A. (34°N, 84°W) are presented and compared. Prevailing wind, diurnal and semidiurnal wind amplitudes are considerably larger over Ramey than over Atlanta, but the mean zonal circulation over Atlanta is more characteristic of the equatorial circulation than winds measured by stations at higher midlatitudes. The value of continuous observations, with a height resolution of ±2 km, is again emphasized, as is the need for the application of several techniques, ground-based, in-situ and satellite, if projects such as the MAP GLOBMET are to succeed in delineating the global meteorology of the mesopause.

# Meteor Wind Results from Atlanta, U.S.A. and Ramey, Puerto Rico

by

R. G. Roper
School of Geophysical Sciences
Georgia Institute of Technology
Atlanta, Georgia 30332

## Introduction

The Georgia Tech Radio Meteor Wind Facility is located in Atlanta (34°N, 84°W), and has been in operation since August, 1974. The system has been described by Roper (1975), and results pertaining to both prevailing winds and tides using data from the four years 1974-1978 have been published by Roper (1978 a,b), Salby and Roper (1980), Dolas and Roper (1981), and Ahmed and Roper (1983). No data is available for the period August 20, 1978 through July 14, 1980, when both transmitter and receiving sites were relocated (but still remained within a kilometer of their previous positions).

The French (CNET) Meteor Wind Radar, dsecribed by Glass et al. (1978), was installed at a site near Aguadilla, Puerto Rico, during the summer of 1977. The site (18°N, 67°W, see Fig. 1, from Mathews et al., 1981) is located approximately 44 kilometers from the west-north-west of the 430 MHz Thomson scatter radar and other facilities at the National Astronomy and Ionosphere Center, Arecibo Observatory. The CNET radar has been described by various authors as the Aguadilla Radar, the Punta Borinquen Radar, and, as in this paper, the Ramey Radar. Only the zonal component of the wind at meteor heights is measured.

The Arecibo Thomson scatter radar has provided meteor zone wind measurements (Mathews, 1976) prior to the installation of the Ramey meteor wind radar. However, Arecibo is a multi-use facility, and cannot be dedicated to any one task for more than a few days at most.

Other meteor radars have been operated in the tropics. In a pioneering effort, Babadzhanov et al. (1970) reported meteor winds from Mogadishu (2°N, 45°E) for the period 22-29 September, 1968. The University of the West Indies has provided useful data from Jamaica (18°N, 77°W) as reported by Alleyene et al. (1974) and Schloefield and Alleyne (1975).

Figure 2 (from Mathews et al., 1981) is included to show the excellent agreement between the winds measured simultaneously at Ramey (M) and Arecibo (TS) between 0900 and 1600 hours, August, 1978.

## Equatorial Winds

Before the Ramey radar was taken over by Georgia Tech in 1978, the Groupe Radar Meteorique of CNET had conducted several campaigns, each of which lasted approximately 10 days. Data from one of these campaigns (August 24 - September 2, 1977) is presented here to illustrate some of the features of the equatorial circulation. Figure 3 shows the results of lowpass filtering of the data, which eliminates the tidal and gravity wave components, leaving periods of greater than one day. The most obvious periodicity present has a period close to 2 days. This is the first recording in equatorial latitudes of the 2 day wave which has received considerable attention at middle latitudes in both the northern and southern hemispheres.

Figure 4 presents the results of a day by day analysis of the 24 hour component of the wind specturm. The fact that the maximum amplitude of this component is 60 m $sec^{-1}$ (considerably larger than is normally measured at midlatitudes), strongly suggests this is a symmetric mode diurnal tidal wind.

Figure 5 illustrates the variation with time of the 12 hour zonal component, with an apparent modulation of the 12 hour periodicity at approximately 7 days.

Figure 6 presents the zonal prevailing, 24 and 12 hour component amplitudes for the period March 17-24, 1979. These results, the first produced under Georgia Tech operation of the system, are somewhat controversial, in that the large amplitudes in all three components on March 21 (which accompany a zonal wind reversal from easterly to westerly above 90 km) appear anomalous.

Ramey and Atlanta Winds: February - June, 1981

Figure 7 details the monthly mean winds determined for the period February through June 1981, the only period for which long term means are available simultaneously from both sites. Some problems were encountered at both sites during the period because of F region backscatter folding back into the meteor region (range ambiguity). This phenomenon is a problem only at times of high sunspot activity, and is not present for most of the sunspot cycle.

While winds are weaker over the "midlatitude" station (Atlanta is 34°N), strong winds and shears in both height and time are characteristic of the euqatorial (Ramey, 18°N) winds. However, as has been noted previously in Atlanta data, if one simply characterizes the zonal mean wind in terms of "easterly" or "westerly" circulation, it would appear that Atlanta is on the fringe of the equatorial circulation, since its "spring reversal" appears much later than is normally the case for midlatitude stations.

Figures 8 and 9, of the diurnal and semidiurnal amplitudes respectively, have not been analyzed in detail, but are included to emphasize the much larger tidal amplitudes observed at Ramey, compared to Atlanta.

## Mesopause Circulation Variability

Figure 10, which demonstrates the correlation between wind reversals over Atlanta and midwinter polar stratospheric warmings (discussed in detail in Dolas and Roper, 1980) is included to emphasize the need for continuous monitoring of the variation of the wind with height, which is required for a full understanding of the circulation at mesopause altitudes. This region does exhibit characteristics of a synoptic meteorology.

Obviously, the results produced by one or two stations are not of much use in determining the global nature of this synoptic meteorology. In order to further this aim, a cooperative program has been set up under the auspices of the Middle Atmosphere Program to further the cooperation which has been carried out since 1970 in the IAGA Global Radio Meteor Wind Studies Project, and the URSI/IAGA Coordinated Tidal Observations Program, which included incoherent scatter radar results. This MAP project, GLOBMET (Global Meteor Observations System; for details see MAP Handbook No.7, pg. 20), while oriented towards meteor research, is seeking the cooperation of experimenters using many different techniques (partial reflection drifts, mesospheric scatter radars, lidar, rockets, satellites, etc.) to contribute to the atmospheric dynamics portion of the program, since all available data will be needed if a truly global picture of upper mesosphere/lower thermosphere circulation is to be realized.

Acknowledgments

The research reported here has been supported by the Atmospheric section of the National Science Foundation, which also contributed towards travel funds for the author's attendance at this meeting.

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Alleyne, H., W. Keenliside, G.S. Kent, J.W. MacDougall and A.J. Scholefield, "Observations of Atmospheric Tides Over Jamaica Using Three Different Techniques," J. Atmos. Terrest. Phys., 36, 171, 1974.

Babadzhanov, P.B., B.V. Kalchenko, and V.V. Fedynsky, "Meteor Winds Over the Equator," Izv. Akad. Nauk SSSR, 9, 33, 1970.

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Matthews, J.D., M.P. Sulzer, C.A. Tepley, R. Bernard, J-L. Fellous, M. Glass, M. Massebeuf, S. Ganguly, R. Harper, R.A. Behnke and J.C.G. Walker, "A Comparison Between Thomson Scatter and Meteor Radar Wind Measurements in the 65-105 km Atltitude Region at Arecibo," Planet. Space Sci., 29, 341-348, 1981.

Matthews, J.D., "Measurements of the Diurnal Tides in the 80-100 km Altitude Range at Arecibo," J. Geophys. Res., 83, 505, 1976.

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Salby, Murry L., and R.G. Roper, "Long Period Oscillations in the Meteor Region, J. Atmos. Sci., 37, 237-244, 1980.

Scholefield, A.J. and H. Alleyne, "Low Latitude Meteor Wind Observations," J. Atmos. Terrest. Phys., 37, 273, 1975.

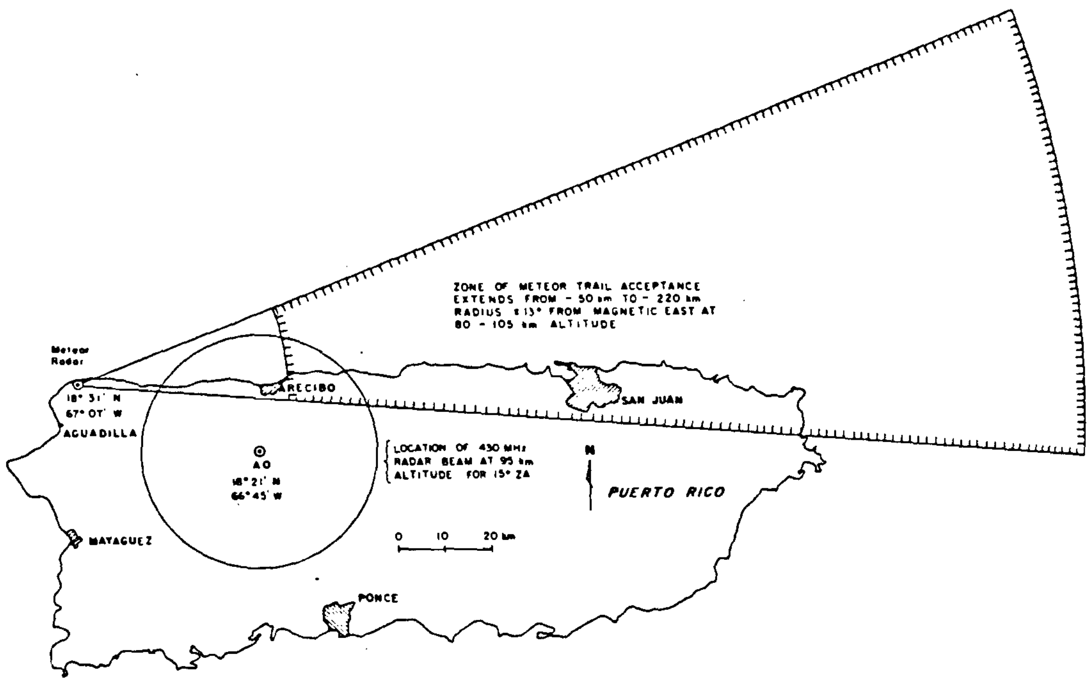



FIG. 1. A MAP OF PUERTO RICO SHOWING THE LOCATIONS OF BOTH THE AGUADILLA METEOR RADAR AND THE ARECIBO THOMSON SCATTER RADAR.

Also shown are projections to ground level of the effective radar beam patterns. Note that the meteor radar collects data from an extensive region while the Thomson scatter pattern lies unresolved on the 15° zenith angle (ZA) circle shown. Thomson scatter radar wind data were collected "looking" both geographically north and east.

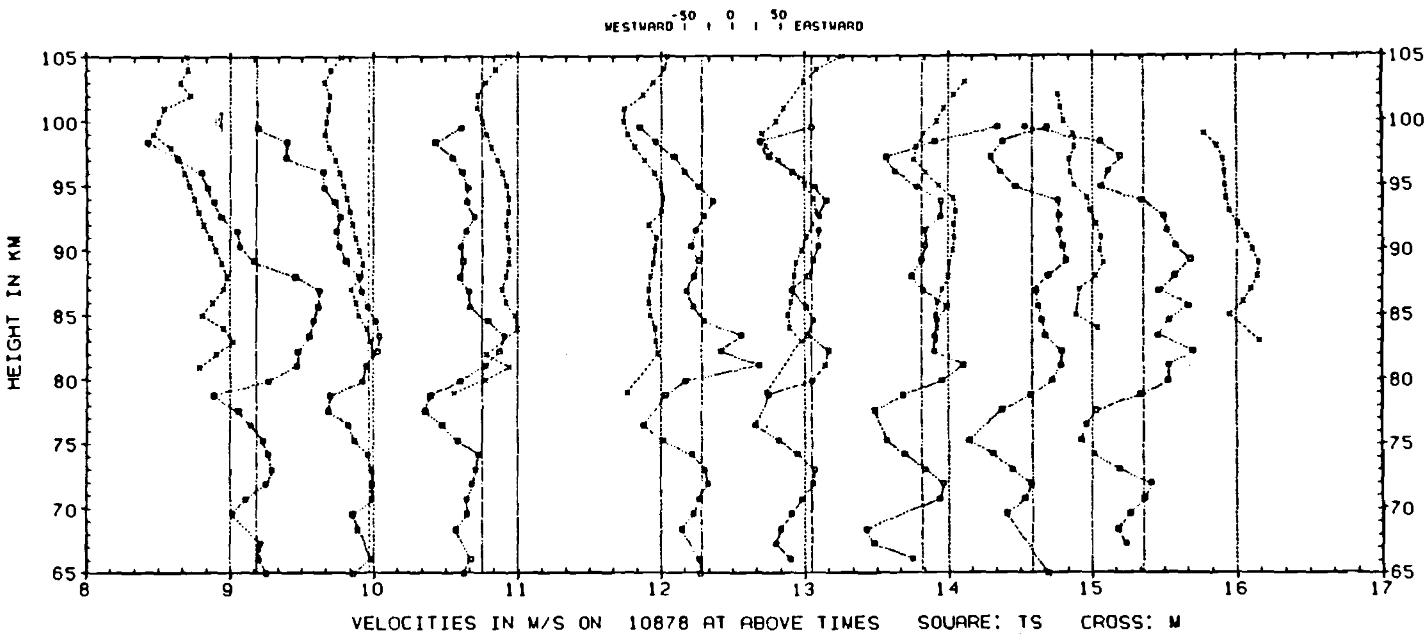
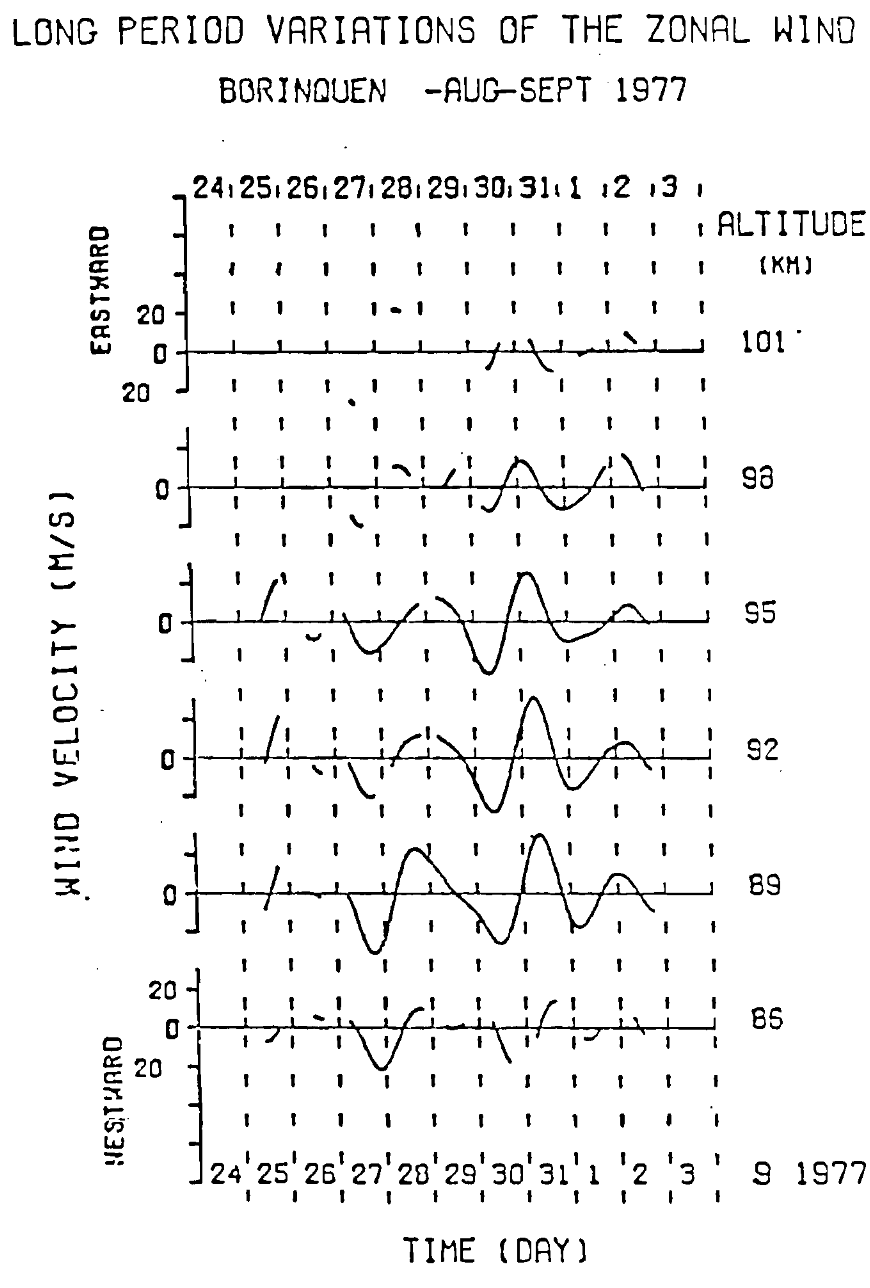



FIG. 2. PROFILES OF ZONAL WINDS MEASURED BY BOTH THE AGUADILLA METEOR RADAR (DASHED LINES AND X'S) AND THE ARECIBO THOMSON SCATTER RADAR (DOTTED LINES AND OPEN SQUARES) ARE GIVEN FOR COMPARISON.

The winds (units of m $s^{-1}$) are plotted versus both height (km) and time (Atlantic Standard Time). The vertical lines indicate both zero velocity (with velocity scale at top of figure) and the central time of the measurement. These results are from 1 August 1978 and only daytime results are given since the Thomson scatter radar (TSR) results are noisy or absent during the night-time hours. Note that the two sets of profiles show the same general shape but that TSR winds seem more detailed than the corresponding meteor results. Also, note that the TSR results extend down to 65 km altitude.


LONG PERIOD VARIATIONS OF THE ZONAL WIND
BORINQUEN -AUG-SEPT 1977
24 25 26 27 28 29 30 31 1 2 3
ALTITUDE (KM)
EASTWARD
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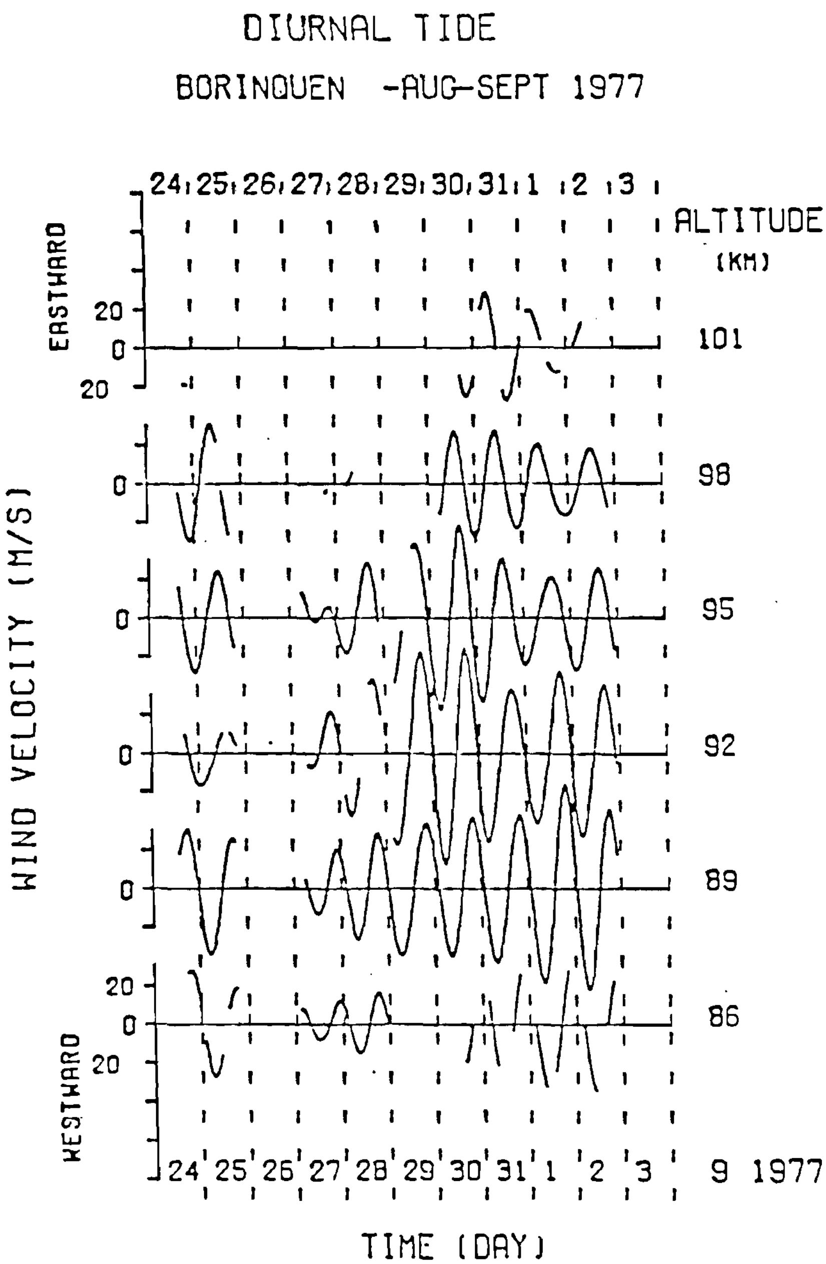
WIND VELOCITY (M/S)
WESTWARD
9 1977
TIME (DAY)

Fig. 3.


DIURNAL TIDE
BORINQUEN -AUG-SEPT 1977
24 25 26 27 28 29 30 31 1 2 3
ALTITUDE (KM)
EASTWARD
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WIND VELOCITY (M/S)
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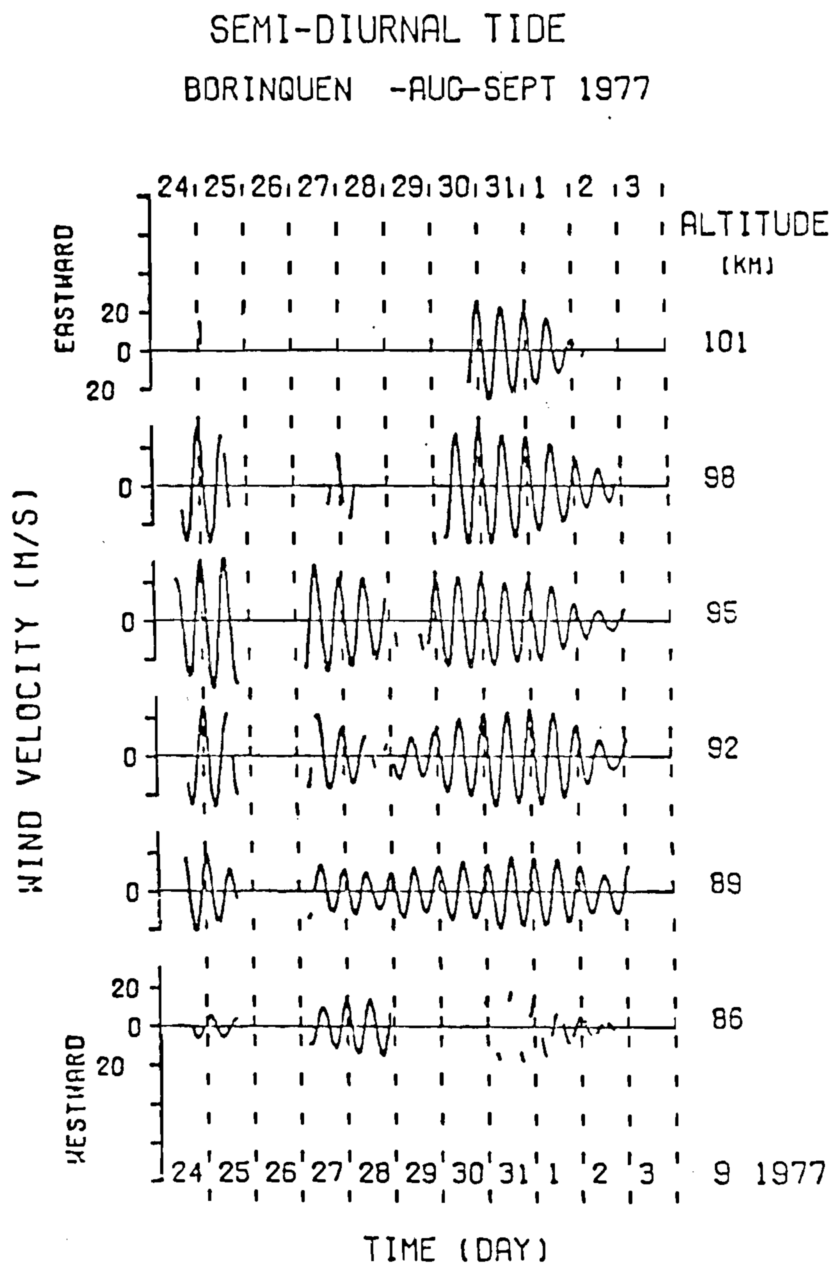
24 25 26 27 28 29 30 31 1 2 3
9 1977
TIME (DAY)

Fig. 4.


SEMI-DIURNAL TIDE
BORINQUEN -AUG-SEPT 1977
24 25 26 27 28 29 30 31 1 2 3
ALTITUDE
(KM)
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WIND VELOCITY (M/S)
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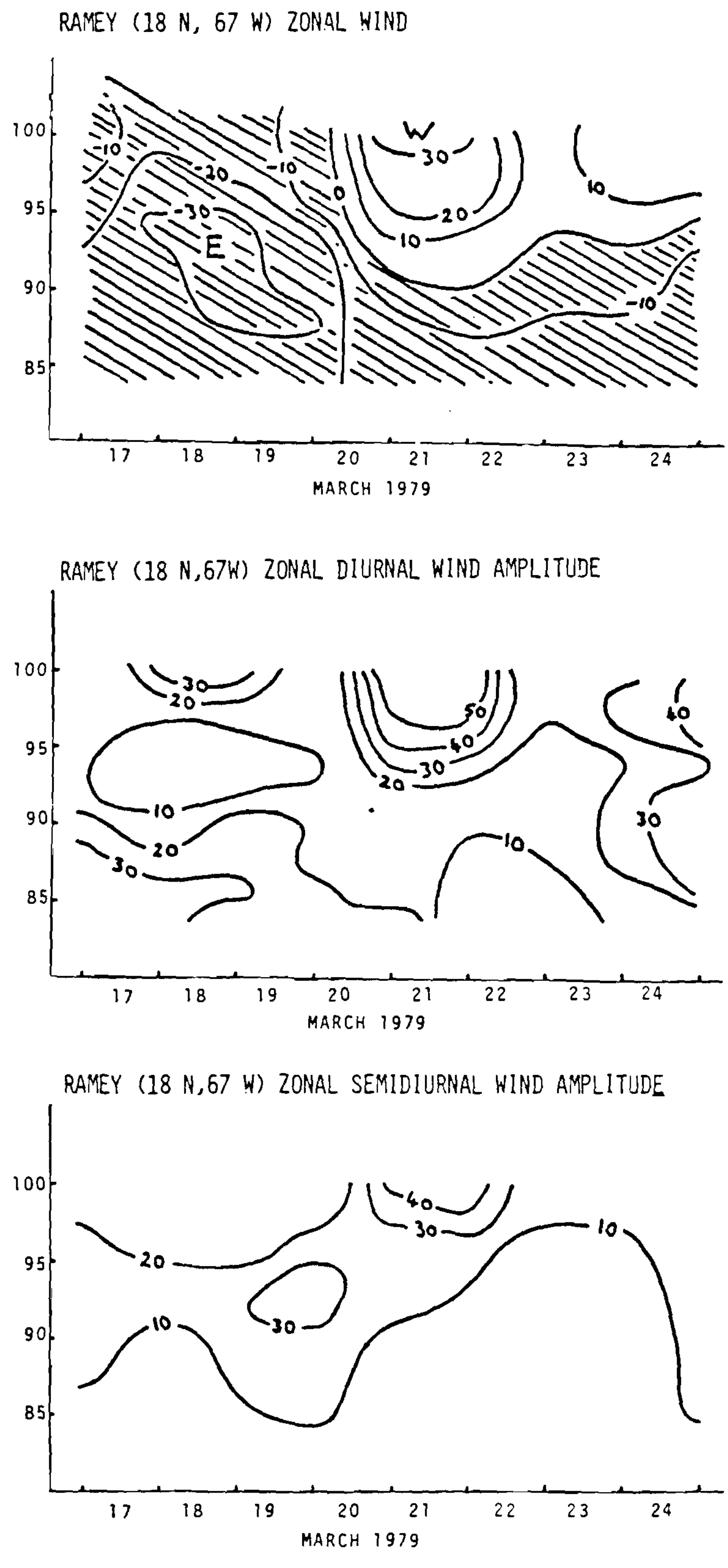
TIME (DAY)

Fig. 5.


RAMEY (18 N, 67 W) ZONAL WIND
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RAMEY (18 N,67 W) ZONAL SEMIDIURNAL WIND AMPLITUDE
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MARCH 1979

Fig. 6.

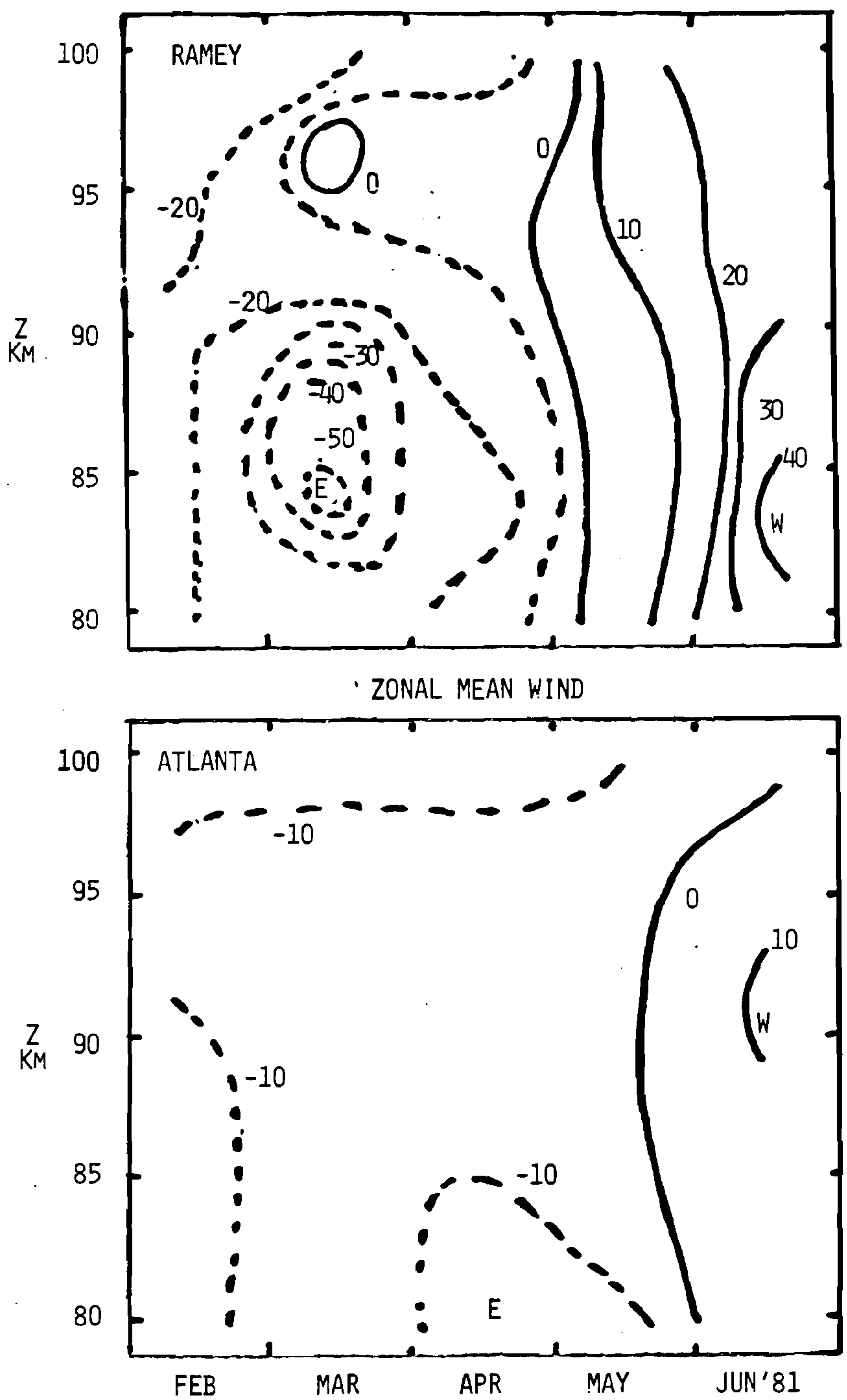

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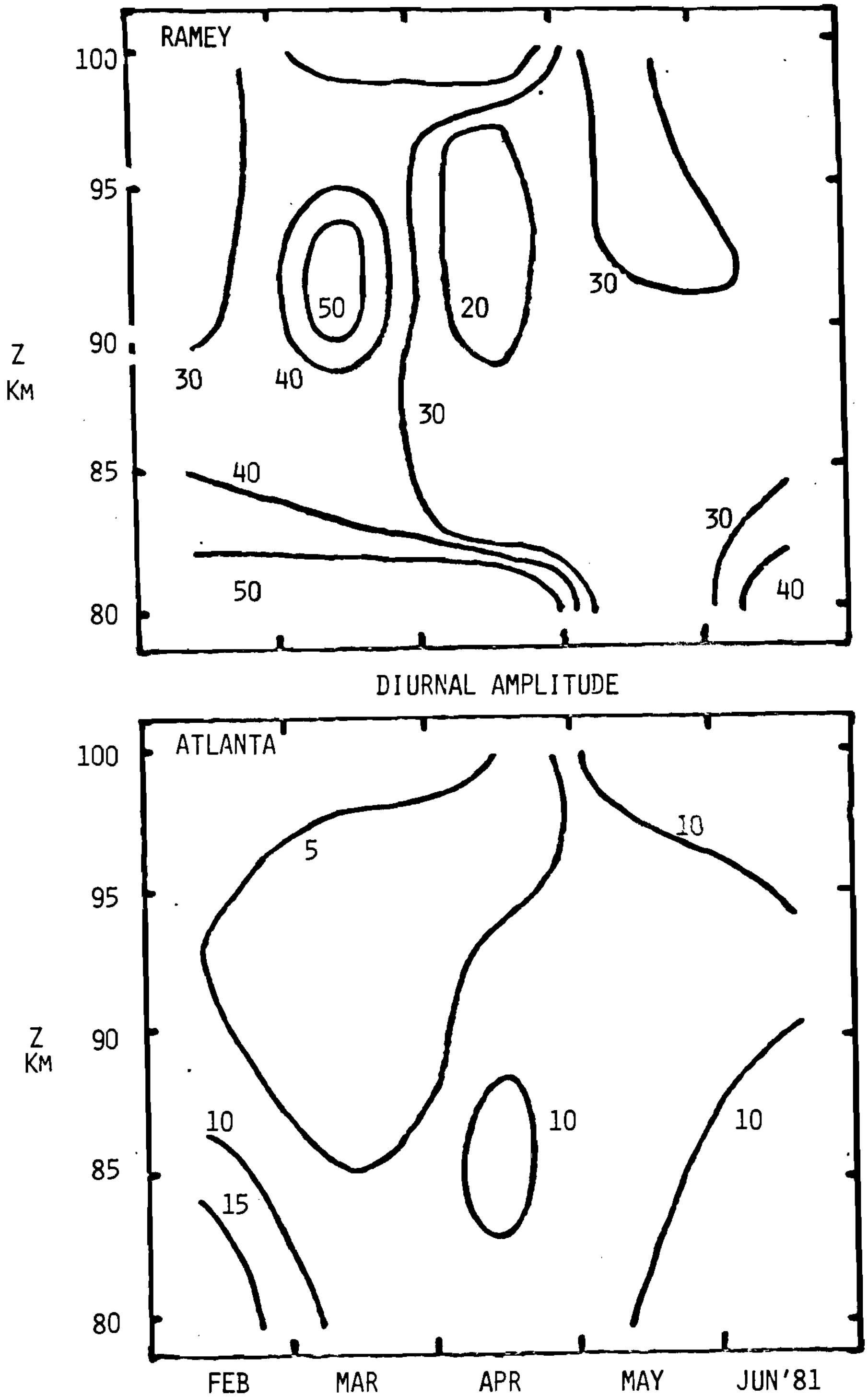
Fig. 7.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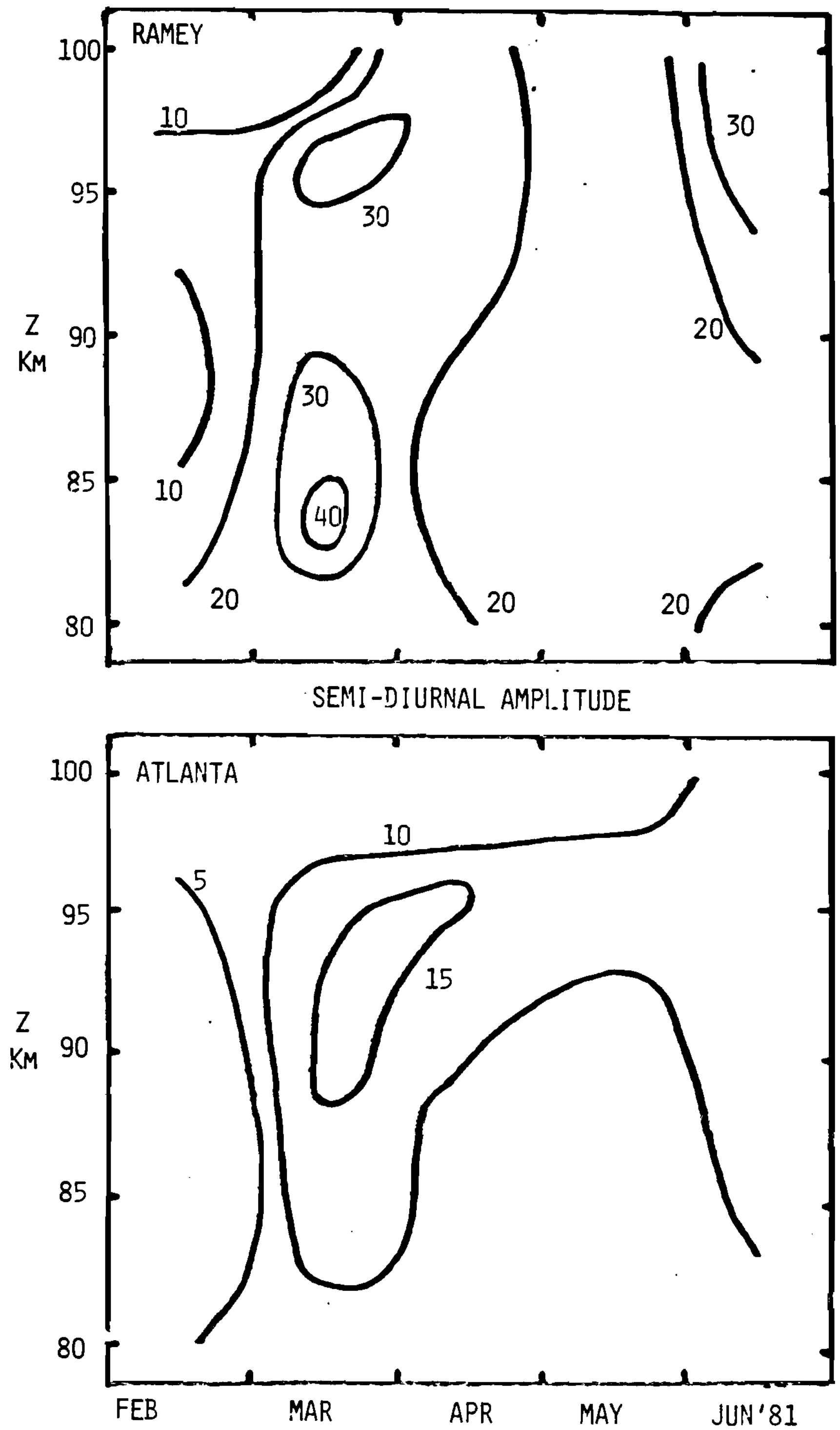
JUN'81

Fig. 8.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SEMI-DIURNAL AMPLITUDE
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JUN'81

Fig. 9.

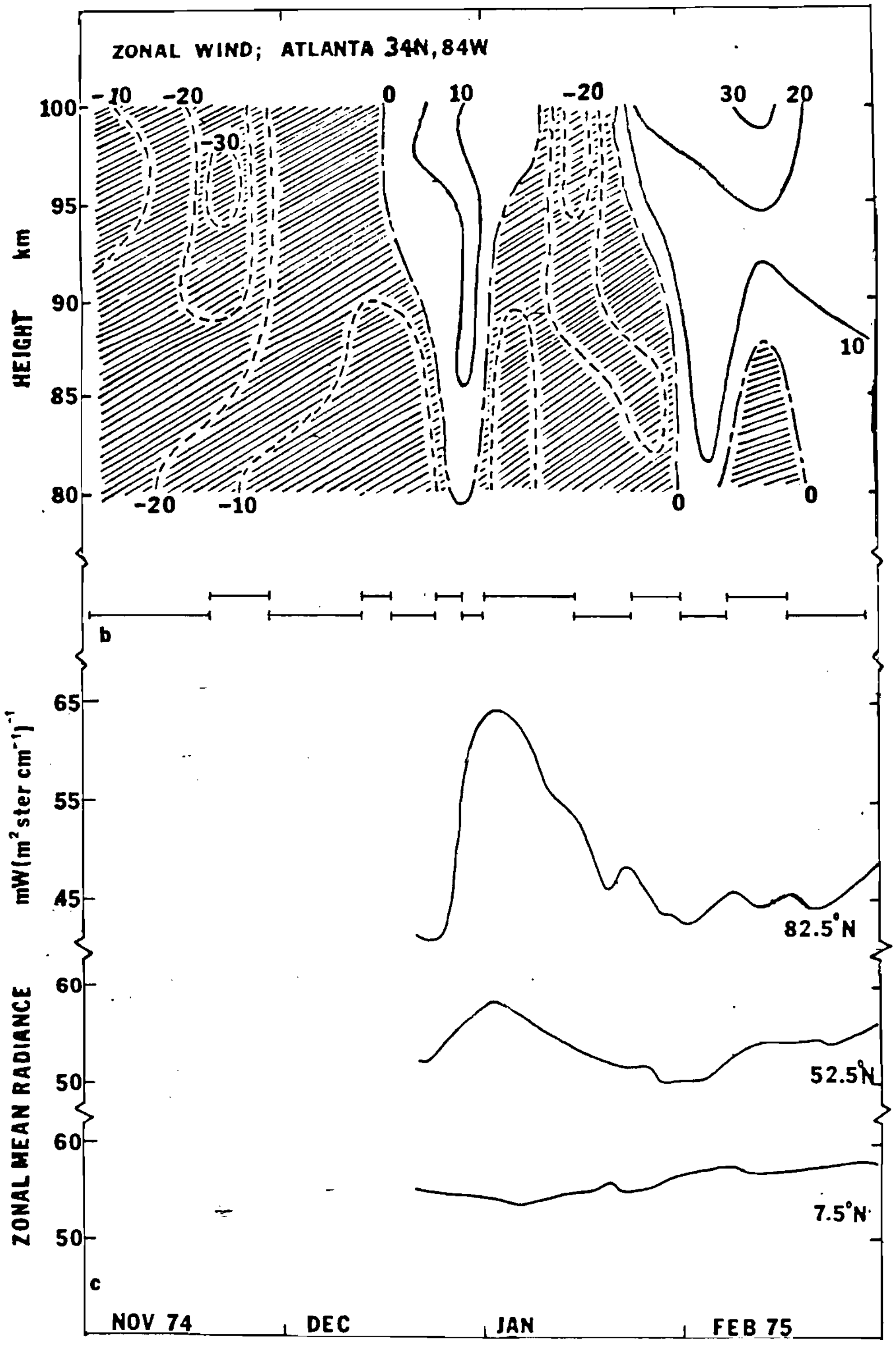



Fig. 10. The mean zonal wind over Atlanta and its variation with height for the period November 1974 - February 1975. The zonal means to which the contours have been fitted are averages for the measurement intervals depicted in b). c) is the mean radiance deduced from satellite radiometer measurements, and is proportional to the stratospheric temperature averaged over the 100 to 5 mb height range.

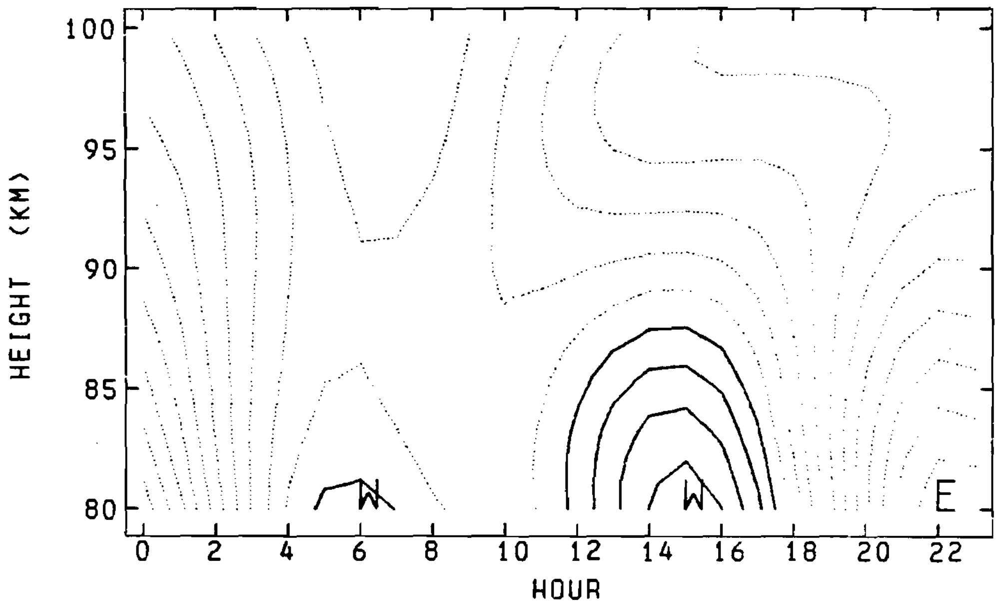
## Chapter II.

As pointed out in Chapter I, many difficulties were encountered in both the acquisition and analysis of the Ramey data. While maintenance of the Atlanta system presented few problems, the Atlanta data suffered just as much as the Ramey data from interference caused by F region backscatter. Contamination of both data sets has resulted in some distortion in the wind patterns. In general, it has been found that monthly means probably best represent the true wind field, although shorter intervals are here compared if one or other system was not operational for the full month.

Considerable difficulty was experienced in the processing of the Ramey data for the month of March (c.f. the March, 1979 data presented in Chapter I). Two factors contribute to this difficulty - contamination by F region backscatter is particularly bad at this time, and the wind field is itself undergoing rapid day to day changes (although one notes that the March 1-7 means agree well with those of March 24-31). The interval March 8-23 proved to be particularly unstable, analysis of this interval producing highly questionable results; which are reflected in the monthly mean as presented.

This more detailed analysis bears out the contention of the first chapter, that, while the Ramey winds are in general much stronger than the Atlanta winds, certain characteristics of the equatorial circulation (for example, the equatorial easterlies) are evident on occasion over Atlanta, where differences in circulation in comparison to stations further north had been previously noted.

## ZONAL WIND



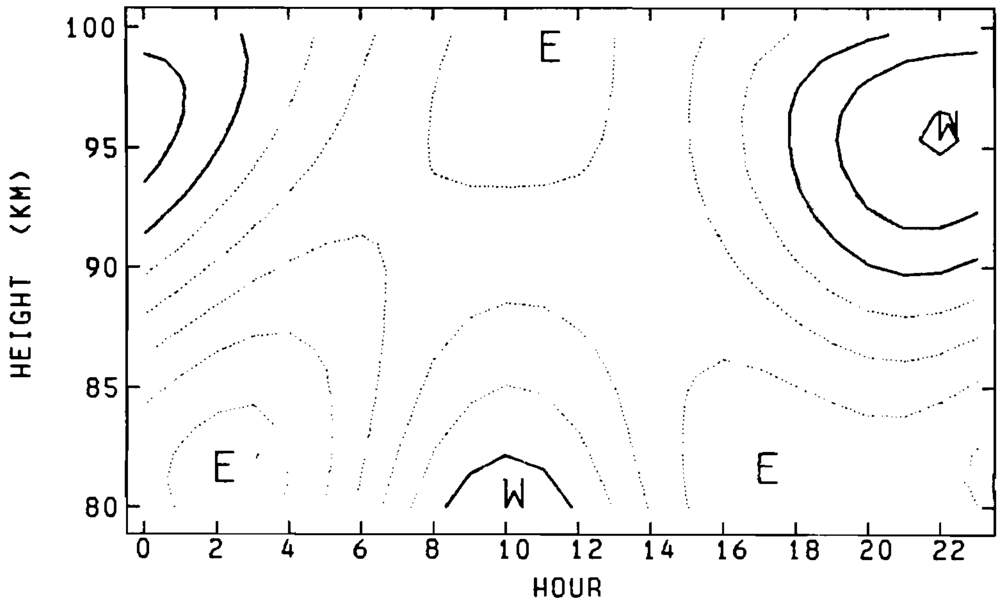

Contours are at 10 m/sec intervals. The first dashed contour adjacent to a full line is the zero contour.

**EAST-WEST WIND COMPONENTS, RAMEY, P.R. (18N,64W)**

**FEB 24 - FEB 27 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -23. | 13. | 30. | 19. | 7. | 2. | 3. | 16. | 5. | 11. |
| 96 | -25. | 11. | 21. | 14. | 7. | 3. | 10. | 15. | 7. | 3. |
| 92 | -24. | 9. | 21. | 15. | 9. | 2. | 11. | 12. | 5. | 2. |
| 88 | -22. | 9. | 32. | 13. | 11. | 1. | 19. | 10. | 4. | 1. |
| 84 | -19. | 10. | 47. | 14. | 11. | 1. | 31. | 12. | 4. | 1. |
| 80 | -18. | 14. | 57. | 18. | 11. | 2. | 42. | 17. | 4. | 1. |

## ZONAL WIND

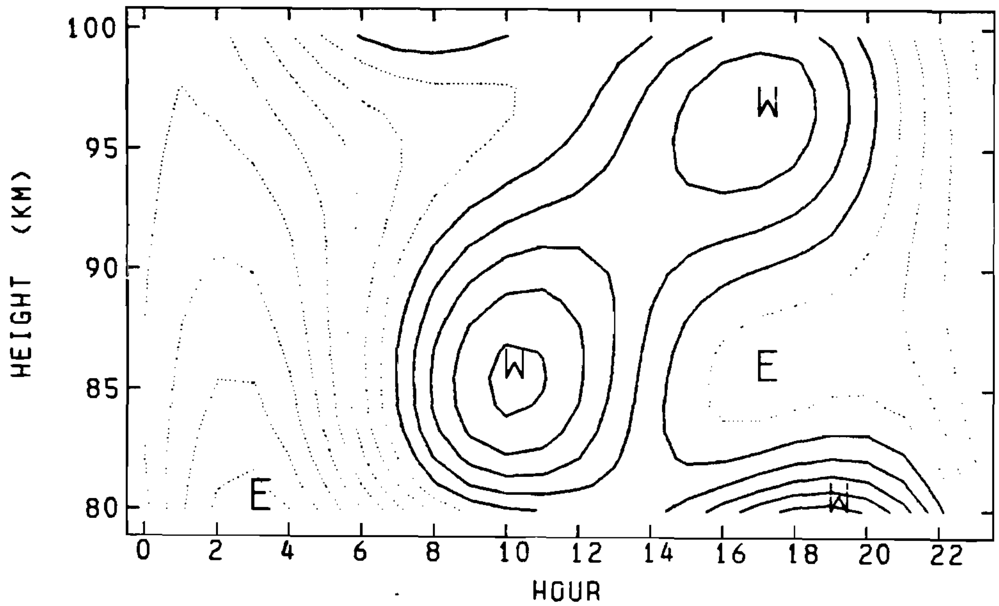



**EAST-WEST WIND COMPONENTS, ATLANTA (34N,84W)**

**FEB 20 - FEB 28 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -7. | 12. | 15. | 17. | 0. | 4. | 4. | 14. | 3. | 7. |
| 96 | 1. | 11. | 27. | 14. | 22. | 2. | 3. | 12. | 10. | 9. |
| 92 | -4. | 9. | 20. | 11. | 21. | 2. | 7. | 10. | 10. | 3. |
| 88 | -14. | 8. | 6. | 11. | 17. | 7. | 9. | 10. | 10. | 2. |
| 84 | -20. | 10. | 17. | 14. | 12. | 3. | 12. | 11. | 10. | 2. |
| 80 | -15. | 12. | 23. | 15. | 11. | 3. | 16. | 14. | 10. | 2. |

ZONAL WIND

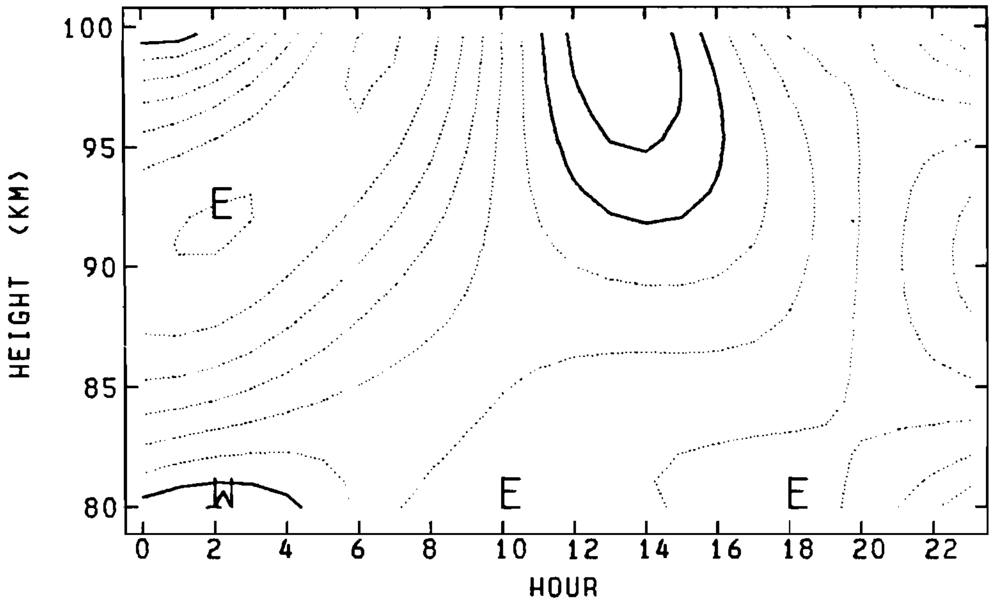



EAST-WEST WIND COMPONENTS, RAMEY, P.R. (18N,64W)

MAR 1 - MAR 7 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 1. | 8. | 23. | 12. | 11. | 2. | 19. | 12. | 7. | 1. |
| 96 | -2. | 7. | 33. | 9. | 15. | 1. | 13. | 9. | 6. | 1. |
| 92 | -3. | 6. | 37. | 7. | 14. | 1. | 7. | 8. | 8. | 2. |
| 88 | -4. | 6. | 40. | 7. | 12. | 1. | 19. | 8. | 9. | 1. |
| 84 | -4. | 7. | 40. | 9. | 13. | 1. | 26. | 9. | 9. | 1. |
| 80 | -3. | 10. | 68. | 24. | 17. | 1. | 25. | 13. | 8. | 1. |

ZONAL WIND

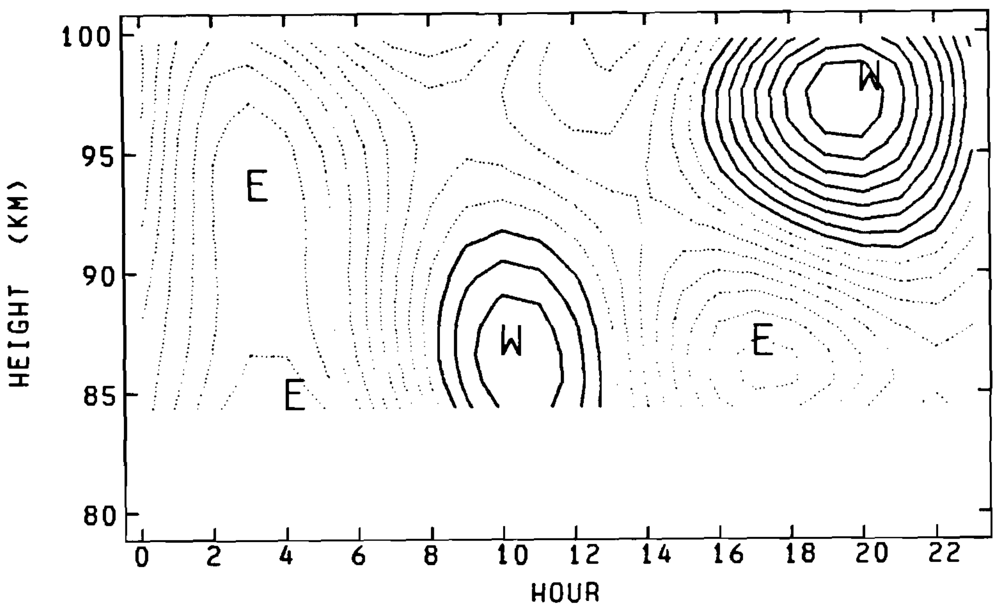



**EAST-WEST WIND COMPONENTS, ATLANTA (34N,84W)**

**MAR 1 - MAR 7 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -5. | 14. | 11. | 16. | 20. | 8. | 36. | 18. | 1. | 1. |
| 96 | -16. | 12. | 29. | 19. | 15. | 2. | 15. | 15. | 1. | 2. |
| 92 | -21. | 10. | 31. | 16. | 14. | 1. | 1. | 12. | 2. | 27. |
| 88 | -20. | 10. | 18. | 16. | 13. | 2. | 5. | 14. | 7. | 5. |
| 84 | -14. | 11. | 7. | 14. | 6. | 9. | 2. | 14. | 5. | 14. |
| 80 | -5. | 14. | 24. | 23. | 2. | 3. | 13. | 19. | 1. | 3. |

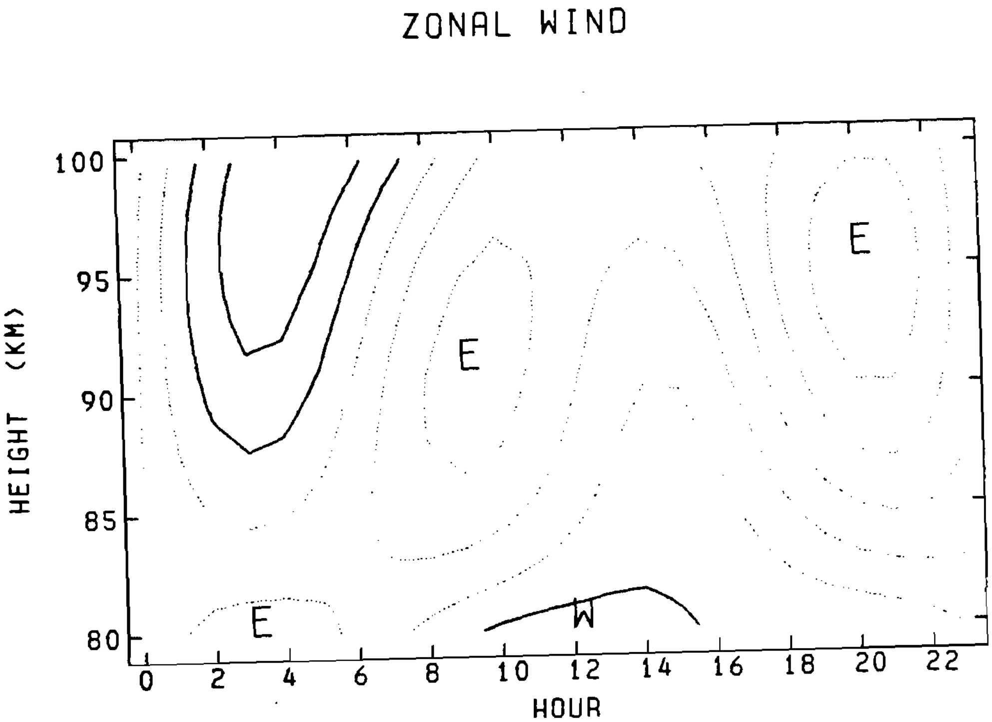
ZONAL WIND




EAST-WEST WIND COMPONENTS, RAMEY, P.R. (18N,64W)

MAR 24 - MAR 31 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -7. | 11. | 8. | 16. | 22. | 7. | 38. | 16. | 8. | 1. |
| 96 | -5. | 10. | 55. | 13. | 18. | 1. | 40. | 15. | 8. | 1. |
| 92 | -18. | 9. | 30. | 11. | 16. | 2. | 33. | 11. | 9. | 1. |
| 88 | -32. | 9. | 33. | 12. | 11. | 1. | 38. | 10. | 10. | 1. |
| 84 | -35. | 10. | 34. | 10. | 14. | 2. | 36. | 11. | 10. | 1. |
| 80 | -12. | 15. | 165. | 29. | 18. | 0. | 43. | 18. | 8. | 1. |




**EAST-WEST WIND COMPONENTS, ATLANTA (34N,84W)**

**MAR 24 - MAR 31 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -9. | 13. | 27. | 17. | 6. | 3. | 12. | 15. | 4. | 3. |
| 96 | -12. | 10. | 23. | 14. | 6. | 2. | 19. | 14. | 3. | 1. |
| 92 | -13. | 9. | 16. | 11. | 6. | 3. | 21. | 11. | 3. | 1. |
| 88 | -10. | 9. | 6. | 10. | 7. | 8. | 17. | 11. | 3. | 1. |
| 84 | -5. | 10. | 6. | 15. | 14. | 7. | 7. | 13. | 3. | 3. |
| 80 | 5. | 10. | 15. | 16. | 15. | 4. | 9. | 14. | 10. | 3. |

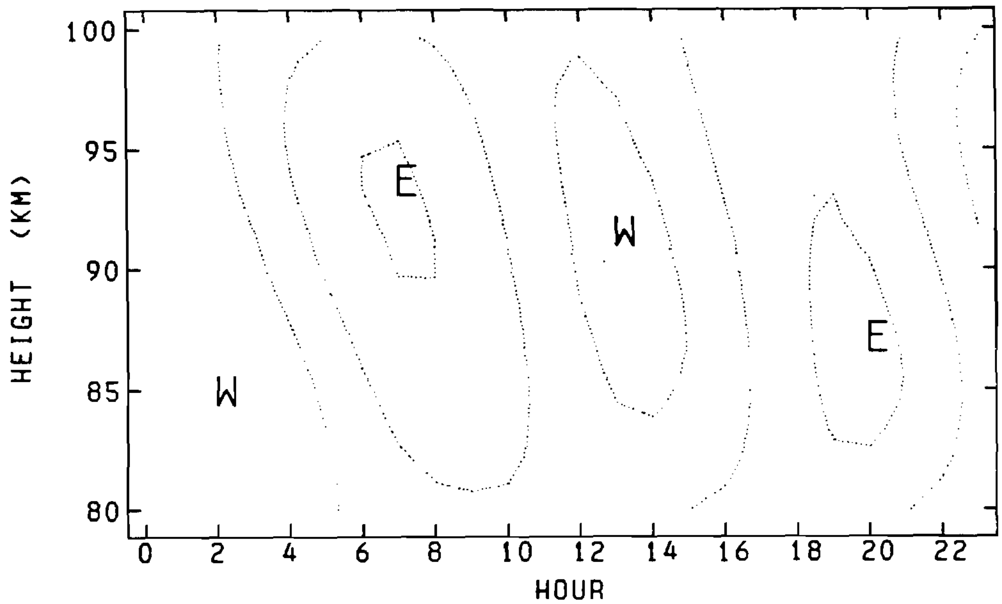
Because of the anomalous diurnal tide amplitudes at 80 and 100 km, the plotter routine became unstable- hence no plot! See text (p. 21) for discussion.

**EAST-WEST WIND COMPONENTS, RAMEY, P.R. (18N,64W)**

**MAR 1 - MAR 31 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -21. | 12. | 250. | 35. | 6. | 0. | 9. | 17. | 8. | 3. |
| 96 | 2. | 9. | 35. | 13. | 17. | 1. | 38. | 13. | 7. | 1. |
| 92 | -13. | 8. | 57. | 11. | 17. | 1. | 22. | 11. | 8. | 1. |
| 88 | -40. | 8. | 36. | 10. | 11. | 1. | 32. | 9. | 11. | 1. |
| 84 | -53. | 9. | 42. | 10. | 13. | 1. | 46. | 11. | 12. | 1. |
| 80 | -26. | 12. | 290. | 35. | 18. | 0. | 21. | 15. | 9. | 1. |

ZONAL WIND

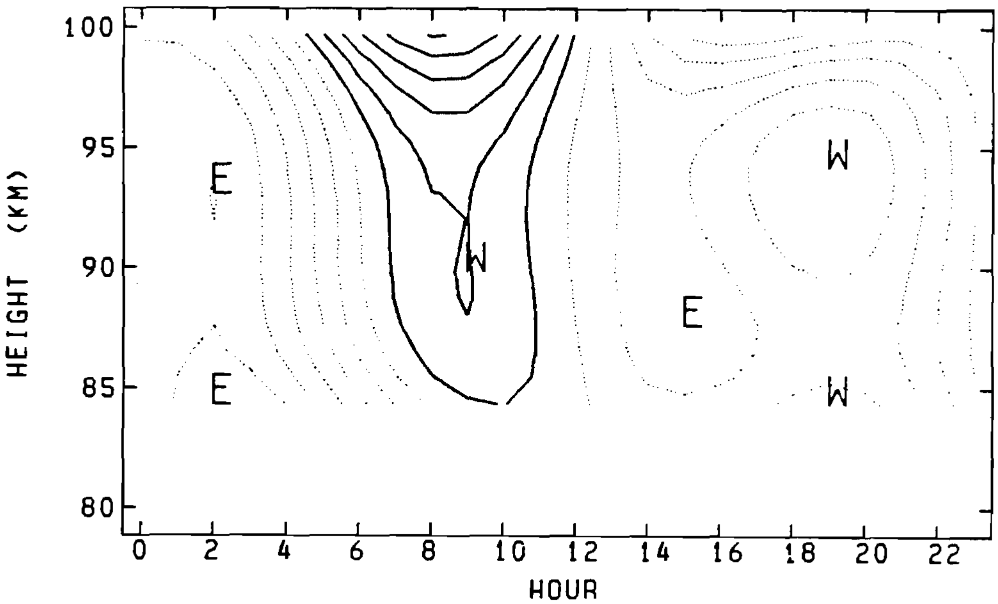



EAST-WEST WIND COMPONENTS, ATLANTA (34N, 84W)

MAR 1 - MAR 31 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -7. | 7. | 6. | 10. | 5. | 6. | 6. | 8. | 0. | 3. |
| 96 | -8. | 6. | 2. | 9. | 1. | 14. | 11. | 7. | 0. | 1. |
| 92 | -8. | 5. | 2. | 7. | 0. | 14. | 13. | 6. | 1. | 1. |
| 88 | -8. | 5. | 3. | 7. | 4. | 8. | 13. | 6. | 2. | 1. |
| 84 | -7. | 5. | 6. | 8. | 4. | 5. | 11. | 7. | 2. | 1. |
| 80 | -5. | 6. | 9. | 9. | 3. | 3. | 3. | 8. | 0. | 5. |

## ZONAL WIND

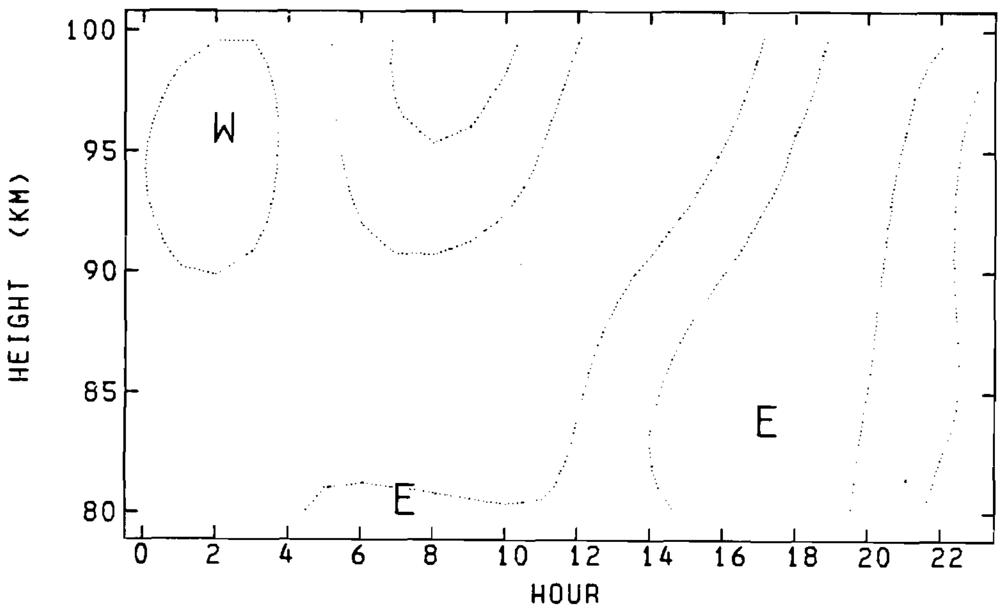



EAST-WEST WIND COMPONENTS, RAMEY, P.R. (18N,64W)

APL 1 - APL 30 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -9. | 4. | 66. | 23. | 8. | 1. | 23. | 6. | 9. | 0. |
| 96 | -8. | 4. | 21. | 4. | 11. | 1. | 23. | 5. | 8. | 0. |
| 92 | -10. | 3. | 20. | 3. | 13. | 1. | 22. | 4. | 8. | 0. |
| 88 | -13. | 3. | 21. | 4. | 12. | 1. | 19. | 4. | 8. | 0. |
| 84 | -15. | 4. | 32. | 10. | 15. | 1. | 18. | 5. | 9. | 0. |
| 80 | -15. | 5. | 114. | 45. | 17. | 0. | 17. | 6. | 8. | 1. |

ZONAL WIND

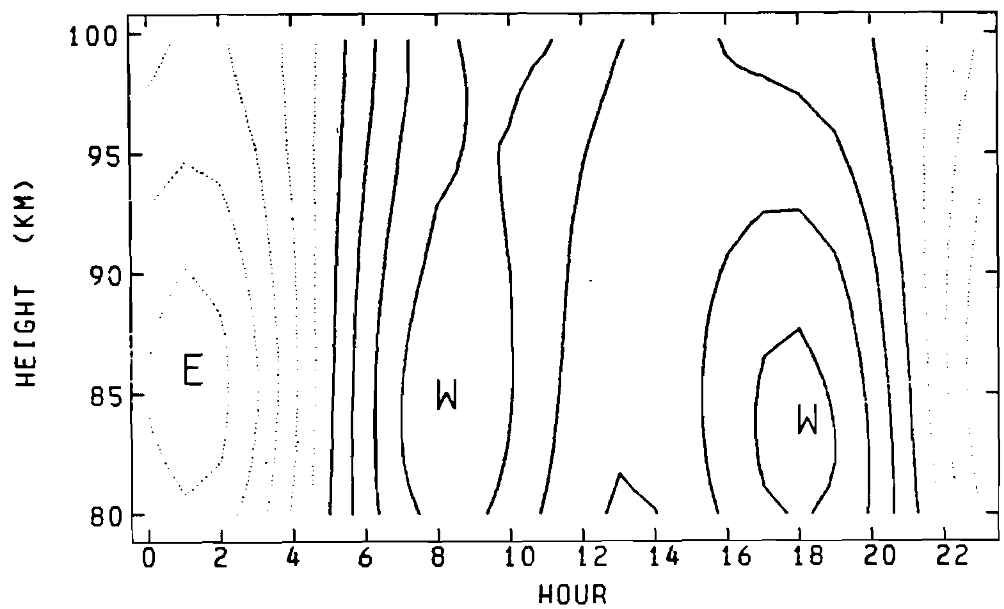



EAST-WEST WIND COMPONENTS, ATLANTA (34N, 34W)

APL 1 - APL 30 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -14. | 5. | 1. | 8. | 13. | 46. | 11. | 7. | 3. | 1. |
| 96 | -10. | 5. | 3. | 7. | 3. | 7. | 12. | 6. | 2. | 1. |
| 92 | -10. | 4. | 7. | 6. | 5. | 3. | 8. | 5. | 1. | 1. |
| 88 | -11. | 4. | 10. | 6. | 6. | 2. | 5. | 5. | 12. | 2. |
| 84 | -12. | 5. | 10. | 6. | 5. | 2. | 5. | 6. | 11. | 2. |
| 80 | -13. | 6. | 8. | 8. | 2. | 3. | 8. | 7. | 0. | 2. |

ZONAL WIND

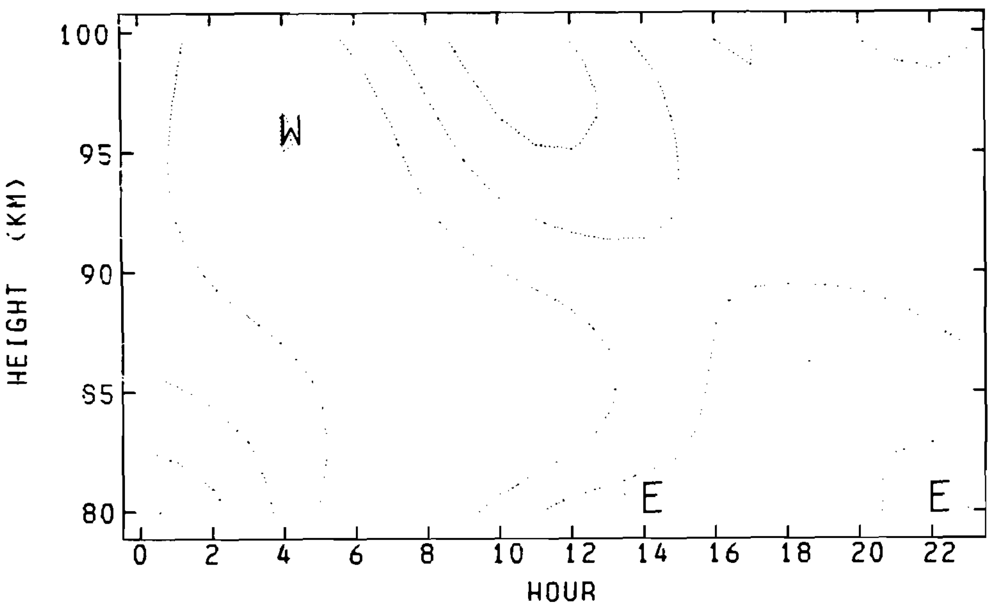



EAST-WEST WIND COMPONENTS, RAMEY, P.R. (18N,64W)

MAY 1 - MAY 14 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 13. | 7. | 27. | 8. | 12. | 2. | 11. | 11. | 9. | 2. |
| 96 | 12. | 6. | 27. | 7. | 12. | 1. | 13. | 9. | 8. | 1. |
| 92 | 12. | 5. | 30. | 5. | 13. | 1. | 19. | 7. | 7. | 1. |
| 88 | 13. | 6. | 34. | 5. | 13. | 1. | 24. | 8. | 7. | 0. |
| 84 | 14. | 7. | 33. | 7. | 13. | 1. | 26. | 9. | 7. | 1. |
| 80 | 14. | 9. | 25. | 10. | 13. | 3. | 22. | 12. | 7. | 1. |

ZONAL WIND

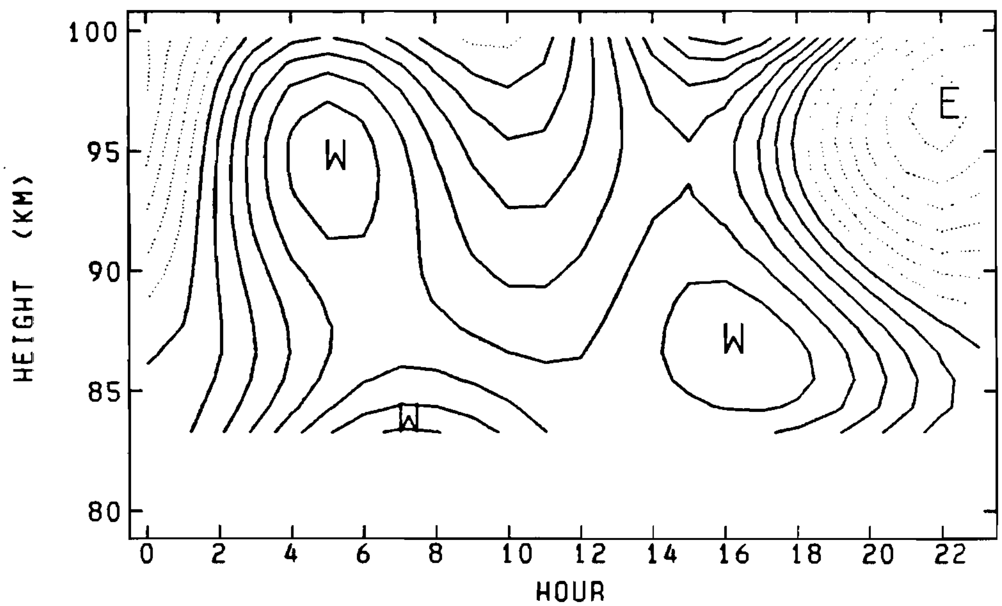



EAST-WEST WIND COMPONENTS, ATLANTA (34N,84W)

MAY 1 - MAY 11 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | -19. | 9. | 4. | 13. | 23. | 12. | 12. | 11. | 3. | 2. |
| 96 | -15. | 8. | 10. | 13. | 1. | 4. | 9. | 10. | 5. | 2. |
| 92 | -13. | 6. | 8. | 9. | 4. | 4. | 4. | 8. | 6. | 4. |
| 88 | -13. | 7. | 10. | 8. | 8. | 4. | 1. | 8. | 10. | 15. |
| 84 | -17. | 8. | 14. | 11. | 9. | 3. | 2. | 10. | 8. | 9. |
| 80 | -25. | 10. | 10. | 12. | 9. | 6. | 16. | 12. | 6. | 1. |

ZONAL WIND

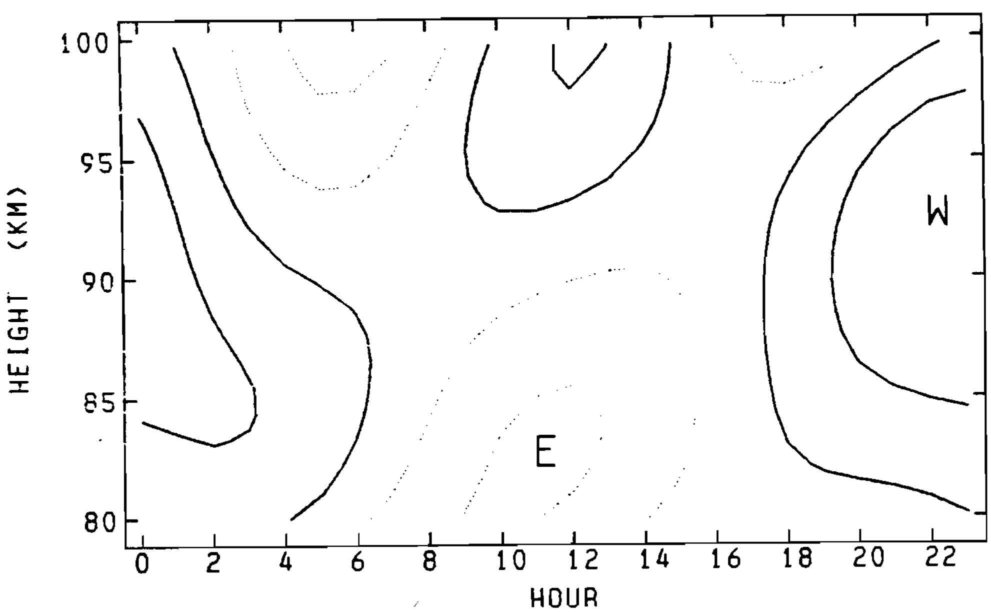



EAST-WEST WIND COMPONENTS, RAMEY, P.R. (18N,64W)

JUN 24 - JUN 29 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 25. | 10. | 80. | 20. | 17. | 1. | 37. | 11. | 5. | 1. |
| 96 | 13. | 8. | 37. | 11. | 10. | 1. | 40. | 9. | 4. | 0. |
| 92 | 22. | 7. | 38. | 10. | 9. | 1. | 31. | 8. | 4. | 0. |
| 88 | 38. | 7. | 22. | 8. | 12. | 1. | 18. | 7. | 5. | 1. |
| 84 | 48. | 7. | 21. | 10. | 11. | 2. | 15. | 8. | 6. | 1. |
| 80 | 40. | 9. | 92. | 21. | 7. | 0. | 16. | 10. | 5. | 1. |

ZONAL WIND




**EAST-WEST WIND COMPONENTS, ATLANTA (34N,84W)**

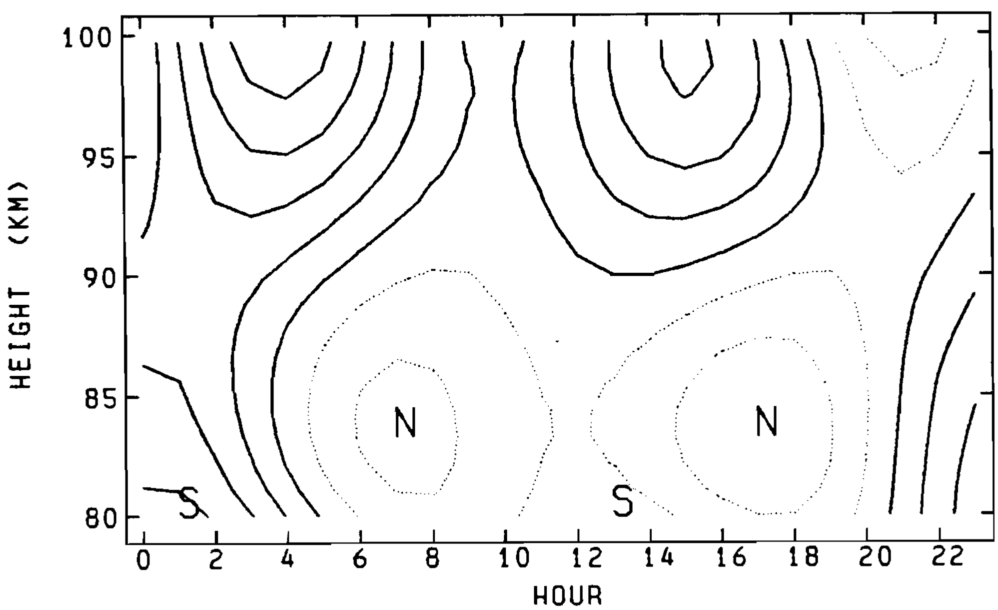
**JUN 20 - JUN 30 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 0. | 8. | 6. | 12. | 14. | 6. | 15. | 11. | 0. | 1. |
| 96 | 9. | 7. | 6. | 8. | 19. | 7. | 11. | 9. | 11. | 2. |
| 92 | 12. | 6. | 10. | 8. | 22. | 3. | 7. | 7. | 10. | 2. |
| 88 | 11. | 6. | 15. | 9. | 24. | 2. | 2. | 8. | 8. | 6. |
| 84 | 7. | 7. | 15. | 10. | 24. | 2. | 4. | 9. | 5. | 4. |
| 80 | 2. | 7. | 8. | 11. | 22. | 5. | 5. | 10. | 3. | 4. |

# Appendix I.

Only the zonal component of the wind has been considered in the previous chapters. Since the meridional component is measured by the Atlanta system, this component is detailed in the subsequent pages of this appendix.

MERIDIONAL WIND

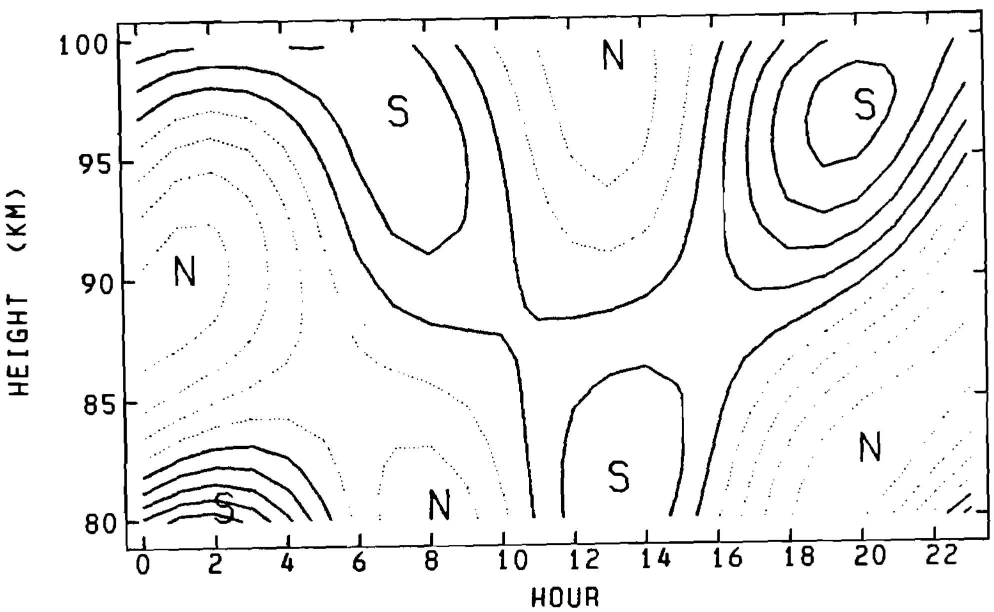



NORTH-SOUTH WIND COMPONENTS, ATLANTA (34N,84W)

FEB 20 - FEB 28 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 22. | 10. | 16. | 12. | 7. | 4. | 28. | 12. | 3. | 1. |
| 96 | 22. | 9. | 8. | 10. | 7. | 7. | 20. | 11. | 3. | 1. |
| 92 | 14. | 7. | 5. | 11. | 3. | 7. | 10. | 9. | 3. | 2. |
| 88 | 5. | 7. | 12. | 11. | 1. | 3. | 11. | 9. | 0. | 2. |
| 84 | 2. | 8. | 18. | 12. | 1. | 2. | 16. | 10. | 0. | 1. |
| 80 | 14. | 11. | 18. | 17. | 1. | 3. | 15. | 12. | 1. | 2. |

MERIDIONAL WIND

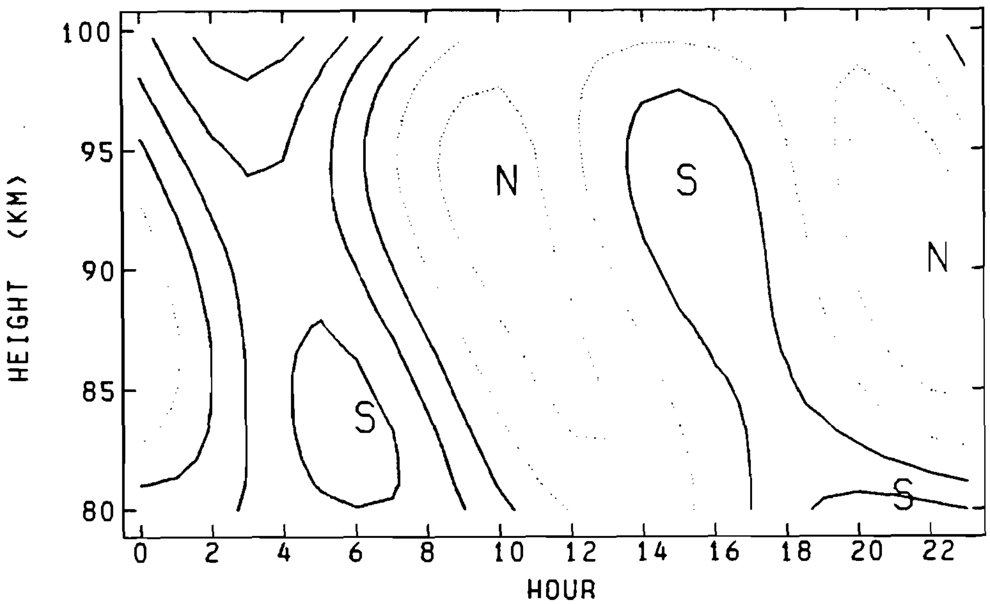



**NORTH-SOUTH WIND COMPONENTS, ATLANTA (34N,84W)**

**MAR 1 - MAR 7 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 19. | 14. | 29. | 21. | 1. | 2. | 5. | 16. | 6. | 6. |
| 96 | 16. | 11. | 15. | 12. | 21. | 5. | 26. | 13. | 7. | 1. |
| 92 | 6. | 9. | 16. | 15. | 15. | 3. | 23. | 11. | 7. | 1. |
| 88 | -3. | 10. | 23. | 16. | 13. | 2. | 8. | 12. | 6. | 3. |
| 84 | -3. | 11. | 17. | 15. | 10. | 4. | 20. | 14. | 2. | 1. |
| 80 | 14. | 14. | 26. | 23. | 2. | 2. | 39. | 17. | 1. | 1. |

MERIDIONAL WIND

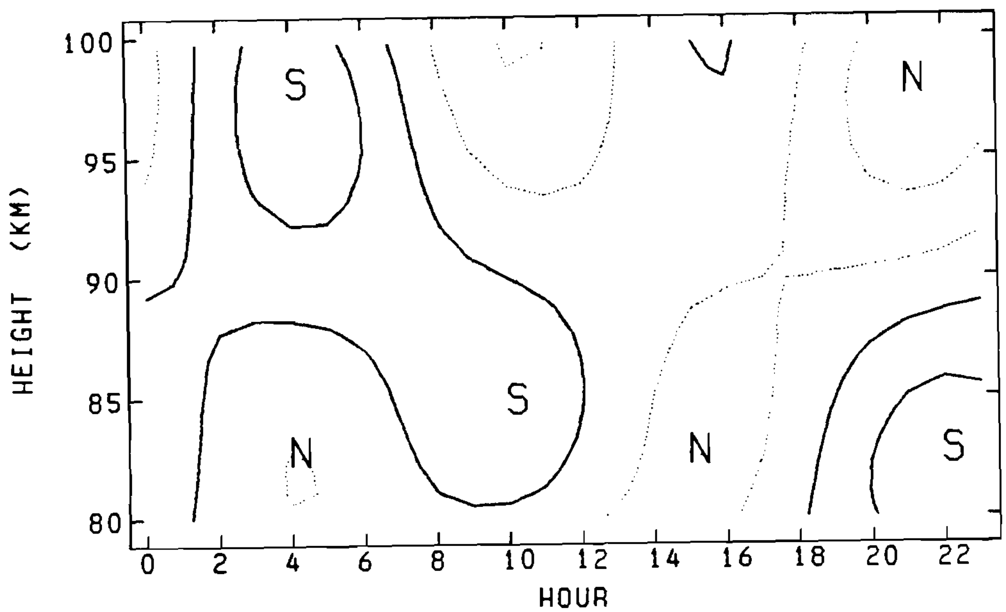



NORTH-SOUTH WIND COMPONENTS, ATLANTA (34N,84W)

MAR 24 - MAR 31 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 12. | 11. | 30. | 17. | 3. | 2. | 8. | 14. | 3. | 3. |
| 96 | 6. | 9. | 11. | 14. | 3. | 4. | 18. | 12. | 3. | 1. |
| 92 | 3. | 8. | 6. | 11. | 5. | 7. | 20. | 9. | 4. | 1. |
| 88 | 4. | 7. | 9. | 10. | 6. | 4. | 18. | 9. | 5. | 1. |
| 84 | 9. | 8. | 11. | 11. | 5. | 4. | 15. | 10. | 6. | 1. |
| 80 | 19. | 9. | 13. | 13. | 1. | 4. | 9. | 12. | 8. | 2. |

MERIDIONAL WIND

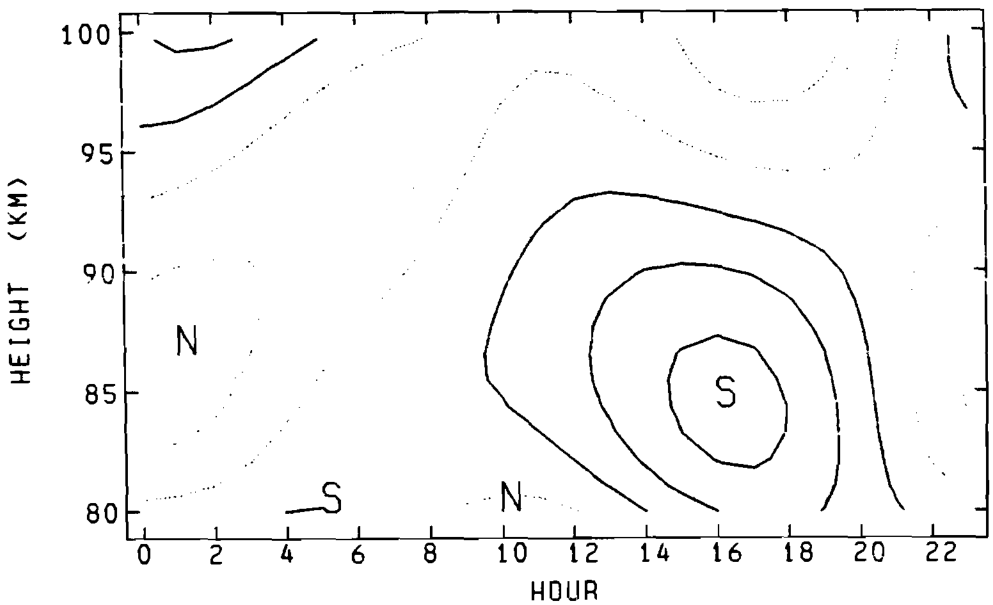



NORTH-SOUTH WIND COMPONENTS, ATLANTA (34N,84W)

APL 1 - APL 30 1981

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 2. | 5. | 5. | 7. | 5. | 4. | 14. | 6. | 4. | 1. |
| 96 | 3. | 4. | 10. | 6. | 6. | 2. | 15. | 5. | 4. | 1. |
| 92 | 6. | 3. | 9. | 5. | 6. | 2. | 6. | 4. | 4. | 2. |
| 88 | 9. | 3. | 5. | 5. | 4. | 3. | 5. | 5. | 10. | 2. |
| 84 | 10. | 4. | 5. | 6. | 24. | 4. | 11. | 5. | 10. | 1. |
| 80 | 6. | 5. | 9. | 7. | 22. | 3. | 5. | 7. | 9. | 2. |

MERIDIONAL WIND

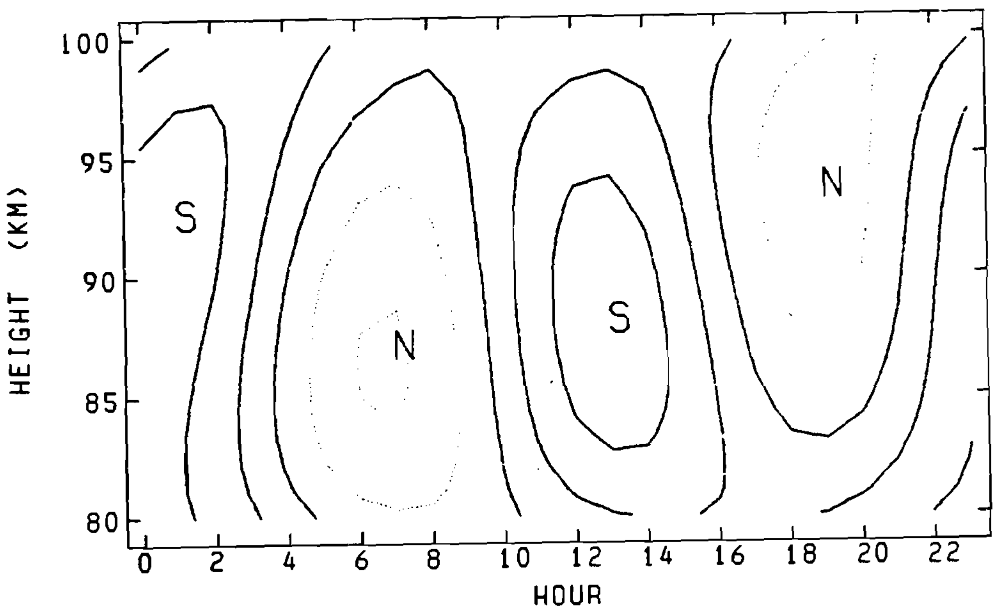



**NORTH-SOUTH WIND COMPONENTS, ATLANTA (34N,84W)**

**MAY 1 - MAY 11 1981**

| | | | 24 HOUR | | | | 12 HOUR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 3. | 8. | 18. | 12. | 3. | 2. | 7. | 10. | 1. | 2. |
| 96 | 0. | 7. | 4. | 12. | 1. | 7. | 7. | 9. | 0. | 2. |
| 92 | 3. | 6. | 11. | 9. | 15. | 3. | 2. | 7. | 0. | 8. |
| 88 | 7. | 7. | 20. | 10. | 14. | 2. | 5. | 8. | 5. | 3. |
| 84 | 10. | 7. | 17. | 11. | 15. | 2. | 9. | 9. | 5. | 2. |
| 80 | 7. | 9. | 11. | 11. | 22. | 5. | 6. | 10. | 5. | 4. |

MERIDIONAL WIND




**NORTH-SOUTH WIND COMPONENTS, ATLANTA (34N,84W)**

**JUN 20 - JUN 30 1981**

| | | | 24 HOUR | | | | 12 H)UR | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HEIGHT | MEAN | ERROR | AMP | ERROR | PHI | ERROR | AMP | ERROR | PHI | ERROR |
| 100 | 12. | 6. | 7. | 8. | 7. | 6. | 8. | 8. | 3. | 2. |
| 96 | 15. | 6. | 6. | 7. | 5. | 5. | 14. | 8. | 1. | 1. |
| 92 | 15. | 5. | 1. | 7. | 3. | 20. | 20. | 7. | 1. | 1. |
| 88 | 15. | 5. | 5. | 6. | 18. | 6. | 21. | 7. | 1. | 1. |
| 84 | 16. | 6. | 9. | 7. | 19. | 4. | 16. | 9. | 1. | 1. |
| 80 | 19. | 7. | 13. | 10. | 22. | 2. | 4. | 9. | 1. | 4. |